AGÈNCIA D'ENERGIA
DE BARCELONA

The energy, climate change and air quality plan of Barcelona
(PECQ 2011-2020)

Ajuntament
de Barcelona

Barcelona
pel Medi
Ambient

The energy, climate change and air quality plan of Barcelona (PECQ 2011-2020)

Ajuntament de Barcelona

Barcelona pel Medi Ambient

AGÈNCIA D'ENERGIA DE BARCELONA

Content

Block 3 - THE MUNICIPAL PROGRAMME

SCENARIOS AND ACTION STRATEGIES

Block 4 - THE SCENARIOS

Presentation

In 2002, Barcelona City Council approved the Barcelona Energy Improvement Plan (PMEB). This innovative document provided the frame of reference for the city's energy policy between 2002 and 2010. The 59 projects that were launched have not only made it possible to make improvements in energy efficiency, they have also saved money, promoted local energy sources and reduced greenhouse gas emissions. The city's social and economic partners, as well as the general public, have been actively involved in the projects. As a continuation of the PMEB, the Barcelona Energy Agency (AEB) has drawn up a new plan called the Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020 (PECQ). More extensive than the PMEB, the PECQ deals with the current circumstances not just in terms of energy but also in terms of the climatic situation and the air pollution that affects the city. Led by Barcelona City Council, the new plan needs to promote the positioning of the city in the national and international arenas and to confront the challenges of today. The plan also needs to ensure that the public administration is provided with strategic instruments that lead to improvements in the health of the general public by reducing polluting emissions, promoting the efficient use of energy resources, and reducing greenhouse gas emissions.

The PECQ updates the PMEB and includes actions that are more cross-cutting and more ambitious, that aim to outline Barcelona's energy commitment in the framework of the European Union's Covenant of Mayors: to reduce the emissions of greenhouse gases associated with municipal activity by 20% by 2020. The plan also analyses what has been done to date – the extent to which PMEB projects have been carried out, the obstacles that have hampered progress, the keys to the successes achieved – and puts forward objectives and strategies for the future. The PECQ can be seen as two complementary programmes - one city and one municipal – each of which goes into the data in more detail, separating city consumption from municipal activities. This is one of the main new features of the Plan.

A number of sectoral studies performed by experts in their respective fields provided the basis for preparing the PECQ. The City Programme (PC), along with some of the studies, was coordinated and written by Barcelona Regional, whilst the Municipal Programme (PM) was coordinated and written by the Barcelona Energy Agency – part of Barcelona City Council's Department of the Environment - which also coordinated the PECQ itself.

Executive summary

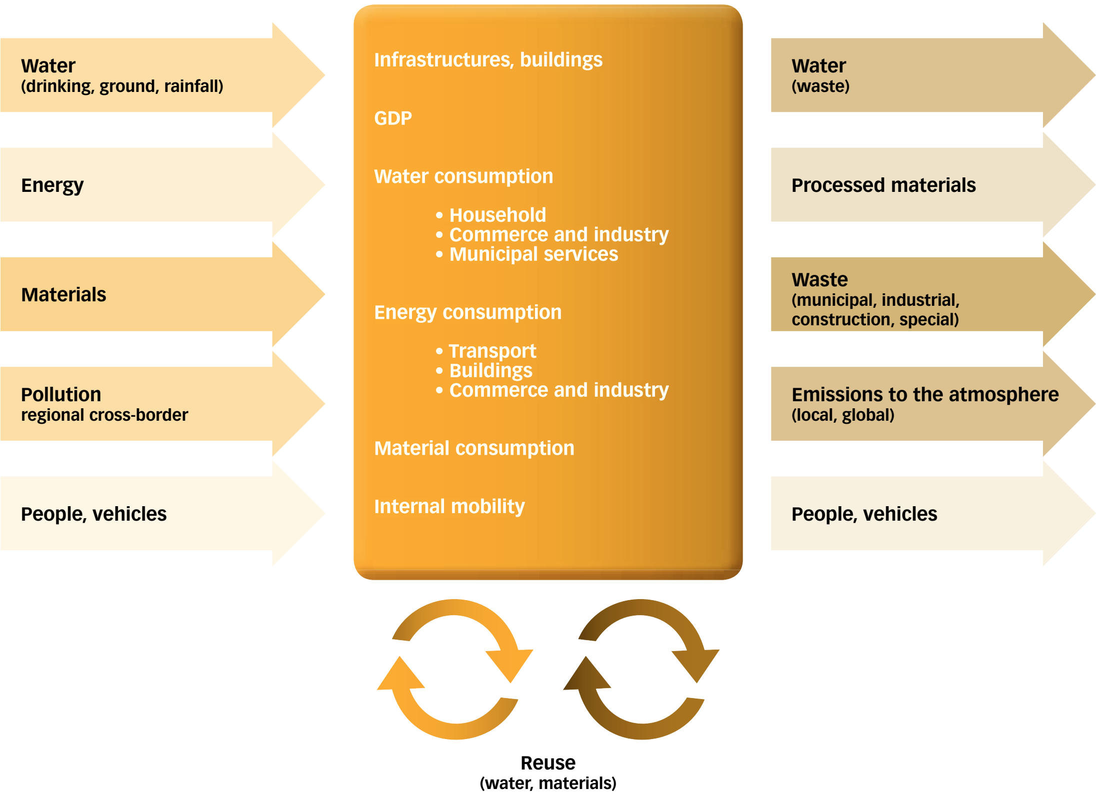
Barcelona's PECQ (Energy, Climate Change and Air Quality Plan of Barcelona) is a plan hosted by Barcelona's City Council aiming to provide Public Administration with strategic tools in order to improve citizens' health, as well as to improve Planet health by increasing energy efficiency and reducing greenhouse gas emissions together with other local effect pollutants.

Since the end of the 20th century, Barcelona is promoting initiatives to reduce the environmental impact derived from municipal activity; and it was in 2002, during a plenary sessions, that the City Council approved the PMEB (Barcelona Energy Improvement Plan for 2001-2010), a municipal action plan provided with a range of projects and measures aiming to increase energy efficiency improvement, to reduce greenhouse gases, and to increase energy generation with sustainable sources.

The results and conclusions derived from the implementation of PMEB projects lead us to talk about a final implementation of 71% of the initially proposed projects. The projects were divided into those which could be directly evaluated in terms of saving emissions of pollutant gas, those which work as a tool to develop other projects, and whose results are hard to be quantified directly. In this sense, the first ones have been carried out up to 65%, while the rest have been carried out up to 76%.

At the end of the projected period for the PMEB, Barcelona's City Council decides to strengthen and to continue its sustainability policy, by developing a new plan, the PECQ: a strategic plan which will set the municipal guidelines and steps to be developed in Barcelona during the period 2011 – 2020, whether in terms of energy efficiency, energy demand management or energy generation through alternative sources.

FIGURE 1 | DISTRIBUTION OF URBAN METABOLISM FLOWS



This new PECQ, therefore, sets the following objectives for the next decade:

- To reduce the increase of energy consumption in Barcelona.
- To reduce the increase of greenhouse gas emissions related to Barcelona.
- To improve air quality in Barcelona especially regarding NO_x and particulate-matter.

Moreover, a series of specific objectives have been settled with regard to the baseline year 2008, such as the accomplishment of international commitments acquired by the City Council, for instance the Covenant of Mayors.

Two parallel programmes

The Plan is structured in two parallel programmes. One of them, at a city level, called City Programme, and the other one at a City Council level, called Municipal Programme, which includes every aspect directly depending on the City Council. This fact will allow clarifying the municipal action scale, which could seem limited but it is outstanding.

Thus, we talk about a City Programme in which all generals aspects concerning the city are discussed, those who depend on the City Council management as well as those depending on the public as a whole.

On the other side, a Municipal Programme referring to those aspects depending exclusively and directly on the City Council (public buildings, public lightning, public fleets and urban services) is created.

The City Programme

The methodology used in the development of the PECQ's City Programme derives from the previously settled one in the PMEB. Technical help has also been offered by different sector work groups which have focused all efforts in specific studies on the city key sectors. Moreover, this PECQ improves certain methodological aspects such as: an in-depth analysis of the city air quality by modelling pollutants dispersion, an analysis of social behaviour concerning energy consumption, an economic analysis of the city as well as the economic effects that can result from the plan measures implementation, or an analysis of the industrial sector, among other methodological improvements already put into practice.

An extensive process of participation has been carried out with citizens and groups of interest in the drafting of the plan, which has gathered more than 250 participants whether experts and organizations or associations representatives, firms, professional associations, trade unions, guilds, political parties, universities and research centres, as well as administrations and public companies. At the end of this process, over nine hundred contributions have been collected.

As shown by the energy and environmental assessment of the city, many of the data and historical indicators compiled during the last years have reflected a constant increase in energy consumption up to year 2005. From this year on, the general tendency observed from the 90's inverts as energy consumption decreases until year 2008.

It is necessary to recall that winter 2005 was one of the coldest winters during the last 12 years, this fact redounded in a crest of energy consumption in heating and sanitary hot water compared to those in previous years. This fact took place not only in Barcelona city, but also in other parts of Catalonia and Spain.

It is also remarkable the fact that the development of the PECQ has met with the economical and financial crisis at a world level, which has affected our country, not only in economical terms, but also, as an after-effect of social behaviour towards saving, deriving in a decrease of energy consumption and, therefore, a decrease of greenhouse gas emissions since 2008.

When summarizing the main energy results of Barcelona, it appears that the final energy consumption in 2008 was of 17,001.78 GWh, which means 10.52 MWh/inhabitant, taking into account the 1,615,908 inhabitants censed in 2008; while in 1999 15,664.78 GWh were consumed, that is 10.42 MWh per inhabitant. This means a cumulative annual growth rate since 1999 of 0.91% in absolute terms of energy and of 0.11% in relative terms per inhabitant.

Energy consumption was distributed as follows: 29.9% in the tertiary sector, 27.9% in residential, 24.1% in transport, 17.2% in the secondary sector and 0.8% in other sectors such as the primary sector, energy, building and public works. Similarly, in terms of energy sources, electricity prevails with 44.5%, followed by natural gas with 31.8%, gas oil with 15.4%, and oil with 7.0%, and LPG (butane and propane) with 1.4%.

The analysis of the energy consumption evolution between 1999 and 2008 shows a rise of intensity in electricity consumption in the domestic sector (especially between 1999 and 2005) as well as in the tertiary sector (especially between 1999 and 2007), which seems to go along with the evolution and rise of the ICT in houses and offices, as well as a larger number and diversity of household appliances and electronic devices found in the market (even though electronic devices have improved in terms of energy efficiency). This increase of electric consumption is thwarted with a high decrease, after 2005, in intensity in natural gas consumption within different sectors which may be initially due to climate effects and, later on, it may be due to the effect of the economic crisis. In 2008, the energy consumption of the secondary sector reached approximately the same level as the previous one in 1999, even though during this period it has not been a constant value, because the consumption increased until 2001; it showed a constant consumption until 2005, and finally it showed a fall of consumption down to the levels of the 90's. Energy consumption in the transport sector, whose figures in 2008 were above those in 1999, shows a light but sustained decrease since 2001. This performance derives most probably from the Public Administration policy in making public transport more competitive than private transport, in addition to a better efficiency of new vehicles.

During this period, the city has had an important economic growth; it must be said the city GDP growth has been superior to energy consumption growth, which suggests that the wealth has been created with less energy demand. So, energy intensity since 2005 has been decreasing (which means a higher energy efficiency of the macro system), showing an annual tax since 1999 until 2008 of -1.11%, up to a figure of 269.44 Wh/€. It is a relatively positive tax in Spain and it is higher than the Spanish reduction values (-1.01% 1999-2008) as well as Europe's (-1.03% 1999-2005).

Considering energy in its origin, during 2008, Barcelona consumed 30,783.6 GWh of primary energy, with a contribution (considering the mix of electricity generation in Catalonia) of 44.8% of nuclear energy, 32.3% of natural gas, 12.3% of liquid fuels, and 3 % of hydro power and renewable energy among other sources of less importance.

According to the annual balance of 2008, 68% of the electricity consumed in Barcelona and Sant Adrià de Besòs was generated by electric generation facilities located in Barcelona and in the Besòs river mouth area. It is expected that, with the new combined cycle power plants (Besòs 5 and the CCPP in the Port of Barcelona), the needs of these two cities and the surrounding area will be fully covered. Therefore, in the short term, Barcelona and its surrounding area will have enough installed power as to export electricity.

It is remarkable that, in the last few years, the evolution of renewable energies in Barcelona, especially solar thermal energy associated to the Solar Ordinance, allowed, in 2008, to have 65,506 m^2 of solar collectors to heat water (in 1999 there were only 2,500 m^2). Moreover, 6,116,5 kWp of installed power in photovoltaic modules are registered (in 1999 there were only 2.5 kWp). In addition, in 2008, photovoltaic power generated by private property firstly exceeded the one generated by municipal property.

With regard to greenhouse gas emissions it is confirmed that, in 2008, 4,053,765.5 t GHG (considering the electric mix in Catalonia) were emitted, which means a ratio of 2.51 t GHG per inhabitant and year. The annual average rise tax since 1999 has been -1.72% (1999-2008); considering that in 1999, 4,737,299.9 tones were emitted, which means a ratio of 3.15 t GHG per inhabitant and year.

It is worth pointing out that not all decreases in GHG emissions between 1999 and 2008 are due to energy efficiency improvement. An important part of this decrease in emissions is due to changes produced in this period for a better treatment of urban solid waste, while another part is due to methodological upgrades of emission factors.

Among greenhouse gas emissions, the transport sector was the main emitter (26.2%), followed by residential (20.6%), commercial and service sectors (19.4%), the secondary sector (13.5%), as well as other sectors (0.5%) such as the primary, energy, building and public works. Some 8.1% of the GHG emissions was also caused by municipal solid waste treatment, and 11.8% was due to the Port of Barcelona activity as well as these related to Barcelona Airport which has a direct impact on the city.

The PECQ has analyzed, through modelling the dispersion of those pollutants with immission levels above the EU legislated values, nitrogen dioxide (NO_2), concentration and particulate matter fewer than 10 microns of diameter (PM_{10}) in the city air which affect, in high concentrations, people's health. This analysis has allowed to know the origin of emitting focus, as well as the possible future scenario which can guarantee the regulatory compliance of set up limits since 2010 by the EU, and, therefore, guarantee an ideal air quality for the public.

As a result of this modelling, and after doing the data calibration from measurement stations located in Barcelona and its surrounding area, it turns out that as an annual average, 65.6% of NO_2 located in the air of Barcelona derives from vehicle engines; 8.6% from the residential sector and the tertiary sector (natural gas and LPG); 4.8% from the secondary sector and energy generation; and 2.1% from the Port of Barcelona, while 0.1% comes from Barcelona Airport. It remains an 8.6% of background pollution (pollution coming from external focus) and 10.1% of local background pollution (internal emitting focus, in the city, with emission levels or emission profiles different to those modelled).

Regarding the origin of PM_{10} in the air, it mainly derives from vehicles (11%), even though an important part comes from out of the city (47.9% of background pollution) and 40.2% is considered local background pollution, so these are unidentified focus or focus with levels or hourly/monthly profiles different from those modelled. The remaining 0.9% are emissions coming from other sectors (residential, tertiary, secondary, etc.).

The scope of this City Programme is as transversal as possible, since energy problems affect almost every aspect concerning the city lifestyle. This analysis is mainly pointed at giving importance to behavioural aspects towards energy, through a social analysis related to the rational use of energy as well as citizens' perception towards climate change, since one of the most important factors to reduce energy consumption includes an efficient management of energy demand.

This Plan's main outcome has been to have identified six segments of population with a different behaviour towards energy and the environment: Aware (29% of population), Comfortable (27%), Dynamic (23%), Passive (17%), Anti-establishment (2%), and Convinced (2%). The Aware and Convinced segments are those more active in saving energy and recycling, while the Comfortable and Passive segments are the less receptive and sceptical in changing their behaviour in order to reduce energy consumption and pollutant emissions. This fact will imply that the PECQ plan of action will have a high factor of social awareness as well as an approach to the public, providing citizens with enough tools and information so they can make their own decisions and take action according to the PECQ's aims.

Another key sector that has been studied in the PECQ is the building energy renovation, a significant aspect in a city with few expansion chances such as Barcelona. In this sense, different proposals have been carried out concerning the direct relation between city planning and energy efficiency.

Mobility, as a main actor in air quality terms and as a consumer of 24% of city final energy, has a key role in this document, as well as other different key vectors in the running of a city such as waste, energy supply quality or local and renewable energy generation.

Any energy analysis is not complete enough if not linked to the city economic sector, from classical actors such as the secondary sector up to key infrastructures such as the Port and the Airport of Barcelona.

This analysis has stated a whole of 85 projects which deal with each and every detected problem. It is worth mentioning that apart from the projects included within the PECQ, measures or projects done and passed before the PECQ have also been added, having a special importance in Barcelona, whether related to energy or pollutant emissions.

The Municipal Programme

The cross-cutting issues referring to energy problems need the complicity of many city sectors in order to reach the goals of a local energy plan with full success warranty. One of the main agents involved has to be the City Council itself, which should take on the environmental challenge in its government lines. So, it is important to settle a Municipal Programme which allows the City Council to take on the leadership in the cause against climate change and the improvement of air quality by means of a municipal action.

The main objective is that the success of municipal action spurs on all citizens to take over the commitments made by the city relating the environment. The proper communications of the City Council's efforts in actions and aspects related to energy saving, efficiency, emissions reduction as well as usage of renewable energies can break the perpetuation of some myths and barriers linked to certain attitudes and technologies.

For this reason, the Municipal Programme works transversally together with other plans of Barcelona City Council (Urban Mobility Plan, Green Spaces Plan, Tourism Plan, etc.), as well as with other municipal actors (lighting, mobility, sports facilities, etc.).

Thus, all aspects considered in the Municipal Programme (such as public buildings, lighting, municipal fleets and urban services) consumed 473 GWh during 2008, and emitted 84,400 tonnes of greenhouse gas, which meant 2.8% of the city total energy consumption. The main consumers in this sector were municipal buildings (52%), followed by public lighting (20%) and waste collection fleet (16%), 9% municipal services and 3% by other municipal fleets. Regarding energy sources, almost 60% of consumption was electricity, 24.5% was natural gas and 11.5% was gasoil. It is remarkable to point out the share of a 1.5% of solar thermal energy, above other sources such as oil (0.5%) and very close to LPG (2%).

The main amount of energy consumption in municipal buildings has derived in the development of a specific subset plan, called PEMEEM (Saving and Improvement Efficiency Plan in Municipal Buildings), which, in the framework of the PECQ, will try to speed up all measures related to municipal buildings.

These municipal consumption rates are the base in order to reach a lowering of related emissions of a 20% facing 2020, with the implementation of the 23 projects which define the Municipal Programme.

All City Council's stakeholders had the opportunity to make proposals and express their opinion in a participation process carried out for the Municipal Programme.

City Programme Objectives

It is expected that all projects included in the PECQ will have an energy reduction potential of 1,678.85 GWh/year (an -10% of 2008 energy consumption), and a 709,000 t/year of GHG emissions (an -18% of 2008 value), as well as 2,742, t/year of NO_x emissions, 288.1 t/years of PM_{10} and 253.3, t/year of $PM_{2.5}$.

After applying the business as usual (BAU) scenario for 2020, and the above mentioned reduction potentials, the expected *"PECQ Scenario"* for 2020 will lead the city to a +10% energy consumption increase (compared to the +19% of the BAU scenario), and a +1% of GHG emissions (compared to the +17% of the BAU scenario).

The price of implementing all the measures was evaluated in 2,431.74 M€, of which about 1,960.22 M€ will be paid by the Barcelona City Council.

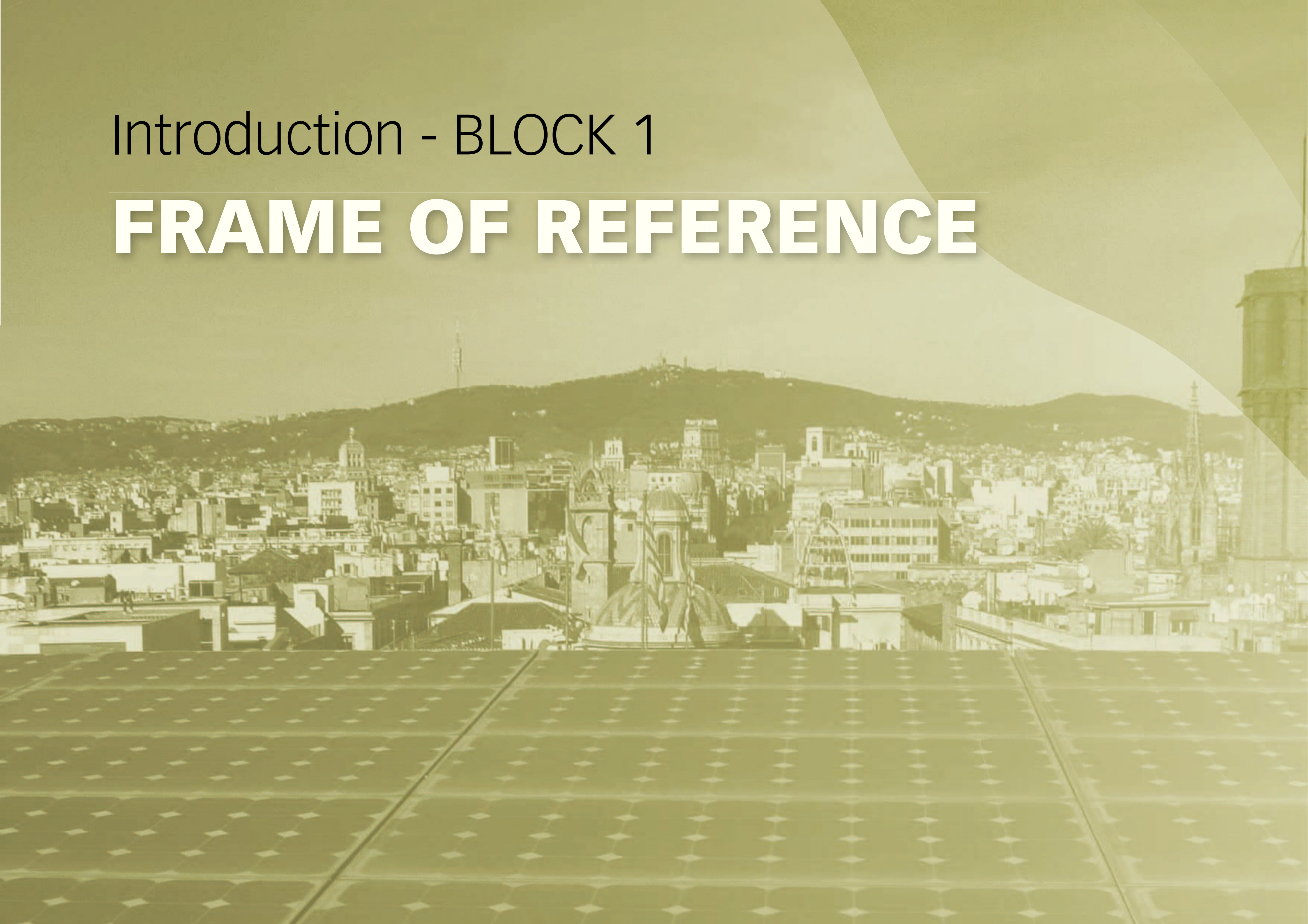
Municipal Programme Objectives

As an extraction of the City Programme, it is expected that the projects included in the Municipal Programme of the PECQ will have an energy reduction potential of 58.2 GWh/year (a -19.59 % of 2008 per capita energy consumption), and 14,827 t/year of GHG emissions (a -23.45 % of 2008 per capita emission value).

With this 23.45% GHG per capita emission reduction for 2020, Barcelona accomplishes the Covenant of Mayors Commitment.

Introduction - BLOCK 1

FRAME OF REFERENCE



1.1 - Scope of the PECQ

1.1.1 - SPHERE OF ACTION

The scope of the Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020 (PECQ) is the city of Barcelona. Nevertheless, the analysis of a number of issues has meant adjusting the limits of the Plan to the functional unit of the study or to the required action, as stated in the sections that follow.

The PECQ covers a ten-year period (2011-2020), coming into force at the end of the implementation period of the Barcelona Energy Improvement Plan (PMEB) on 31 December 2010. It comprises 7 programmes and 108 projects and is structured across 2 parallel programmes, which cover different territorial areas:

- **The City Programme** (85 projects) refers to all the general aspects of the city, except those that are the direct competence of the Municipal Authority. It includes the following sectors: domestic, commercial, industrial, road mobility (excluding municipal vehicles), public transport, energy generation, waste management, etc.

- **The Municipal Programme** (23 projects) is an action plan that encompasses only direct municipal competences. It includes municipal buildings, lighting, public services, green spaces, municipal vehicles and waste collection, etc.

As Barcelona forms part of a wider territory, not only from an administrative and functional point of view (metropolitan area) but also from the perspective of the ecosystem, issues relating to energy management systems, air quality and climate change must extend to, at least, the metropolitan area and cannot be limited to municipal boundaries.

FIGURE 2 | **SPHERES OF THE PECQ**

The PECQ investigates in more depth a number of issues that were covered in the PMEB but that have become more important over recent years

- managing demand, communication and awareness,
- transport networks and electrical supply,
- new fuels and energy sources,
- the impact of large infrastructures (the Port and Airport),
- the current situation of industry,
- energy performance of the City Council's energy facilities and services.

In addition, the PECQ incorporates a number of innovative perspectives with regard to the relationship between energy, air pollution and climate change, as well as consumption and emissions in the distribution of goods.

Furthermore, the PECQ is cross-cutting in nature in that it proposes actions in areas that are covered by other strategic municipal plans and that have an impact on energy related matters: the Urban Mobility Plan, the Infrastructure Master Plan, the project that is evaluating the quality of electricity supply services in Barcelona, and the Tourism Plan, among others.

FIGURE 3 | PERSPECTIVES OF THE PECQ

The relationship between energy and climate change

The relationship between energy and air quality

The perception and social use of energy

The economic impact of energy use

1.1.2 - THE OBJECTIVES

The Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020 (PECQ) is a local administration instrument aimed at the following during that time frame:

- improving energy efficiency and reducing energy consumption in the city,
- cutting the increase of greenhouse gas emissions (GHGs),
- improving urban air quality, in particular with regard to NO_x gases and PM_{10} particles,
- and, improving the quality of energy supply.

Similarly, the PECQ needs to be a means of meeting the city's commitment to reducing GHGs from its municipal activities by 20% by 2020.

To achieve these challenges, a series of specific, strategic objectives are proposed in the PECQ 2011-2020 that set out a diagnosis of, and proposals for, strategic action. These objectives are set out below:

STRATEGIC OBJECTIVES

- Position Barcelona in the current context of energy at the level of Catalonia, Spain and Europe, and redefine its energy strategy with new objectives and action plans.
- Establish a municipal strategy with regard to climate change and air quality, fully coordinated with the energy strategy.
- Raise awareness of the Council's commitment to the above, led by senior figures, and generate a climate of involvement amongst all agents that participate in conceiving and executing the new Plan.
- Position Barcelona in approximately 2020 as a highly competitive city. Energy efficiency, the generation of renewable energy, and air quality need to help bring this about.

SPECIFIC OBJECTIVES

- Involve the general public in the Plan, by means of ambitious projects in the areas of raising awareness, communication, and the positioning of Barcelona City Council vis-à-vis the public.
- Incorporate current and pending planning at local and regional level, as well as new, overarching directives and legislation.
- Define future scenarios that are both possible and desired, and establish quantifiable objectives with regard to such scenarios.
- Determine and define actions and projects to carry out in order to
- achieve the target scenario based on putting forward a range of strategic lines.

FIGURE 4 | OBJECTIVES OF THE PECQ

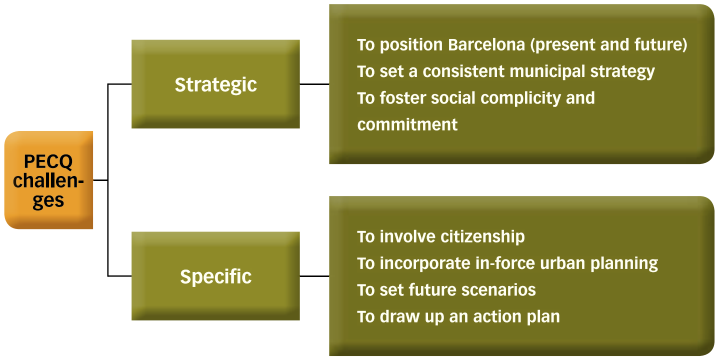
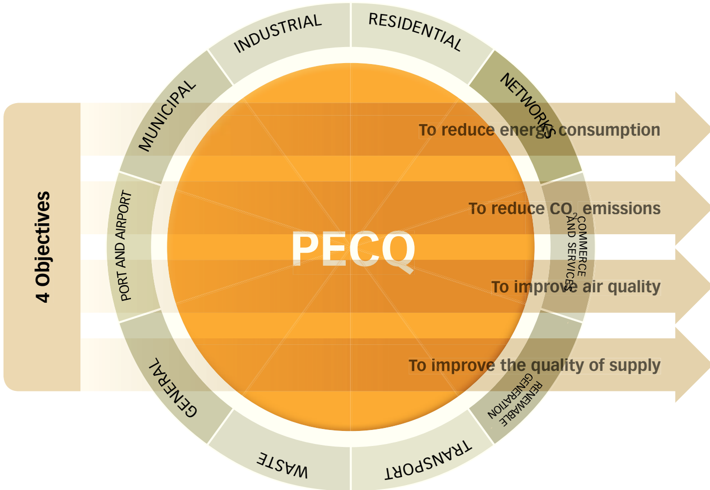


FIGURE 5 | STRUCTURE, CONTENTS AND OBJECTIVES IN THE FRAMEWORK OF THE PECQ



1.1.3 - BACKGROUND

The City's environmental and energy achievements

The city of Barcelona has traditionally been a driving force of initiatives to incorporate environmental issues into urban planning and management and to move forward in the application of the principles and values of a culture of sustainability to municipal policies. This strategy is also evident in terms of energy savings and in the efficient use of energy, and also in the promotion of sources of renewable energy.

After signing the Charter of European Cities & Towns Towards Sustainability (the Aalborg Charter) during the First European Conference on Sustainable Cities and Towns in 1994, Barcelona set up the Commission on Environmental and Sustainability Policy, in 1995, to provide impetus to the process of preparing an Agenda 21 for Barcelona. Three years later, in 1988, the Municipal Council for the Environment and Sustainability was set up and was put in charge of promoting Agenda 21 by means of a participatory forum with the sectors and public and private organisations involved.

Under the Council, in 1999, 13 working groups were set up to prepare reflections and proposals on a set of key issues in the area of the City's sustainability strategy: energy, water, waste, urban areas, education, participation, mobility, economic activity, solidarity and the global impact of Barcelona's urban system.

Subsequently, on 21 May 2002, the Municipal Council for the Environment and Sustainability approved the text of the City Commitment to Sustainability - Agenda 21 in Barcelona. This text was the result of more than three years' work by the Council - and the contributions of hundreds of organisations and people - to define and reach a consensus on ten objectives for the 2002-2012 period. Each of the objectives contained 10 lines of action (100 in total) that covered all aspects of urban life as well as their impact beyond the city limits. Objective number five incorporated lines of action regarding the situation concerning energy in Barcelona.

During the same period, the Municipal Action Plan 2000-2003 was presented. The Plan set down a set of initiatives and proposals aimed at improving environmental quality in the city and introducing a model based on a new energy culture: developing public transport infrastructures, creating green spaces, promoting more sustainable urban design and construction models, promoting clean energy and reducing the energy consumption of municipal buildings, etc.

In the specific area of energy actions, in July 1999 the Solar Thermal Ordinance was passed, coming into force a year later.

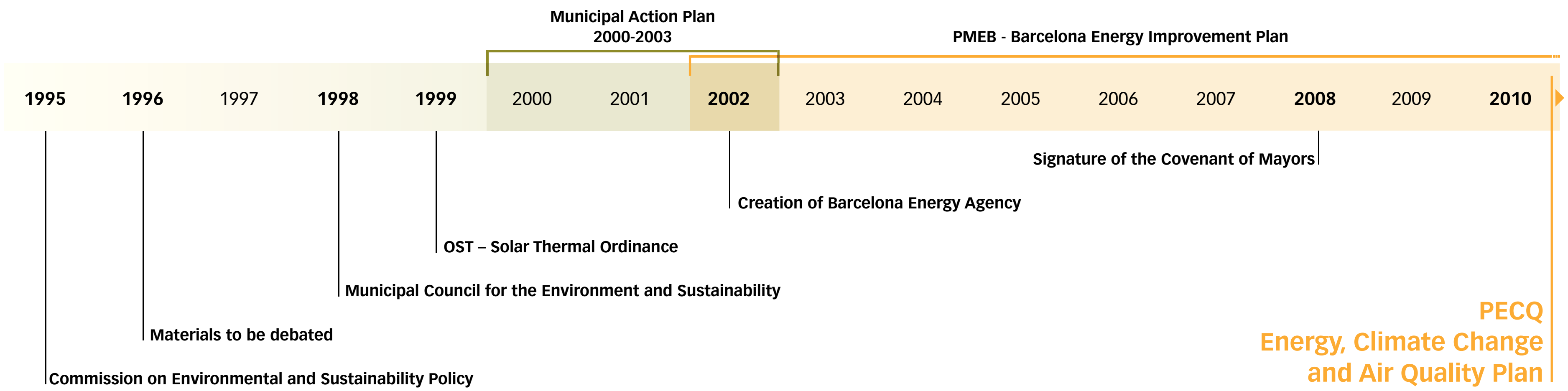
In 2002, the Plenary Council approved the Barcelona Energy Improvement Plan 2002-2010 (PMEB) - a strategic document at municipal level consisting of an analysis covering energy, and emissions of polluting gases and greenhouse gases. The PMEB also contained an action plan with proposals and measures (54 projects, or action units, and 5 complementary projects) to make progress in improving energy efficiency, reducing gas emissions and promoting sources of renewable energy.

In 1996, Barna GEL was set up. Under the umbrella of the European Commission's SAVE programme, it started to carry out the tasks of a local energy agency for the city. In 2002, the Barcelona Energy Agency (as it is known today) was set up as a municipal instrument to carry out measures contained in the PMEB by means of the execution of energy infrastructure projects or renewable energy facilities and also by defining policies covering information, dissemination and raising social awareness with regard to the rational use of energy. The Agency was also set up to monitor energy consumption and gas emissions in the city as a tool to control and monitor the development and impact of the projects carried out.

In 2008, Barcelona signed the European Union's Covenant of Mayors - an initiative promoted in 2007 to contribute to the reduction of greenhouse gas emissions. This was part of a package of Energy for a changing world measures taken by the European Commission aimed at unilaterally reducing CO_2 emissions by 20% by 2020, increasing energy efficiency by 20% and ensuring that 20% of energy comes from renewable sources.

The Covenant of Mayors aims to bring this challenge down to a local level with the active participation of the general public and proposes reducing emissions from signatory cities by 20% (against a base year) by 2020. The Covenant was the result of an informal consultation process between a large number of European cities and is open to all cities, irrespective of their size. This document is a response to that commitment.

FIGURE 6 | THE PECQ - BACKGROUND



Implementation of the PMEB, 2001-2010

According to a monitoring report on the PMEB in 2010, the overall project implementation status (calculated as the average implementation percentage) was 71%. There were 33 finished projects (56%) and 19 were underway (32%). It was not possible to start 7 (12%) of the projects. With regard to evaluable projects[1] (27), some 65% were implemented, whilst the figure for instrumental projects[2] (32), was 76%.

In terms of sectors, those that had the highest degree of implementation were, in descending order: Others, Distribution networks, and Transport. By contrast, those with the lowest degree of implementation were Residential, Offices, and Services and Commercial. At a medium level of implementation were Public buildings and equipment, and General. For programmes, in descending order: Education, Information and communication, Renewable Energy, and Management. By contrast, those with the lowest degree of implementation were Energy efficiency, and, considerably lower down, Consumption savings. In the middle was Regulatory review.

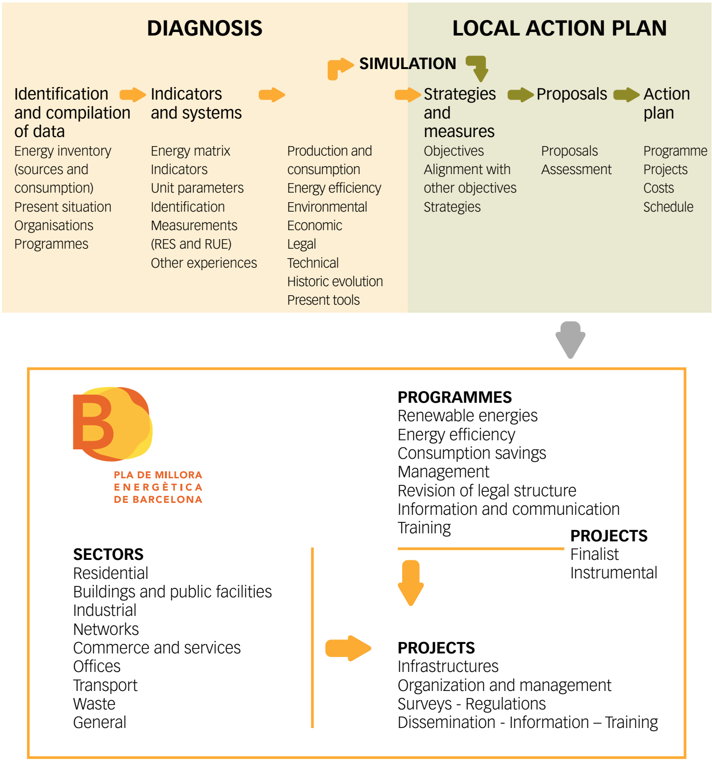
Overall, the following conclusions can be drawn:

- The degree of development of the projects was not uniform.
- The evaluation of progress in some projects cannot only be quantitative (based on the percentage of implementation) - it also needs to be qualitative.
- The collaboration with socioeconomic partners and with the city's energy sector has been positive, although this still needs to be developed further.
- Efforts need to be stepped up in the public infrastructure sector and also in instrumental projects by means of actions such as studies and regulations.
- The collection of statistical information needs to improve in order to have a more complete database that allows for indicators to be developed.
- A process of reflection is required to look at the difficulties of carrying out projects where co-generation is the main technology.
- In the future, projects need to be promoted related to savings, energy efficiency and legislation in the residential and services sector.

1. Evaluable projects are projects that can be evaluated directly in terms of energy savings or polluting gas emissions.

2. Instrumental projects: tools for the development of other projects. Instrumental projects are difficult to quantify directly.

FIGURE 7 | PHASES AND PROJECTS OF THE PMEB (2001-2010)



In terms of energy savings, carrying out the projects in the PMEB were estimated to involve the annual generation of 148,731 MWh of electricity with yearly energy savings of 779,876 MWh. To date, it is estimated that approximately 80,000 MWh have been generated and more than 428,000 MWh saved as a direct result of applying the projects.

In terms of conclusions for the future, the monitoring report proposes the following:

- The need to differentiate municipal actions (the responsibility of, and are carried out directly by, Barcelona City Council) from city actions (general aspects related to the Council's management and the conduct of, and actions taken by, the general public as a whole).
- The need to prioritise the management of demand in the overall approach to energy, as well strategic lines, actions and projects in the new energy plan. The Council, as the closest public administration to the general public, needs to be involved in raising awareness amongst the population, and to enable knowledge to be turned into action.
- The new Plan needs to be less analytical and much more executive.
- It is important to work with the largest possible number of actors involved - at municipal level, any other actions and plans being promoted in other areas or sectors of the Council need to be taken into account.
- The generation of renewable energies, savings and energy efficiency must continue to be the main foundations of both the Plan and the city's energy policy.

1.1.4 - METHODOLOGY

The PECQ continues the methodology applied in developing Barcelona's first energy improvement plan (PMEB) covering 2002-2010. The starting point has been the knowledge base and data that have been updated over recent years and that have been published in successive documents entitled El Comptador (The Counter) by the Barcelona Energy Agency via the Energy Observatory.

As was the case with the process of conceptualising the PMEB, the PECQ received technical support from different sectoral working groups (details are given later in this document), which have contributed a cross-cutting vision that has enriched the project. Various meetings were also held with interest groups that contributed with their opinions, reflections and suggestions. The PECQ, however, extends and improves the diagnostic work carried out during the preparation of the PMEB with new aspects and themes, and also updates specific emission and energy efficiency factors. Noteworthy amongst these changes and improvements are:

- The study of air quality in Barcelona, modelling the dispersion of pollutants and detecting their origin.
- The categorisation of vehicles that drive around the city and their pollutant emission levels.
- An analysis of social attitudes towards energy use.
- An economic analysis that may derive from executing the Plan from the perspective of new business opportunities, new jobs, etc.
- A study of the economic and environmental effects of the Port and Airport on the city.
- An updating of the emission factors of different pollutants in accordance with internationally applied methodologies.
- An analysis of industrial energy performance.
- A detailed study of the public buildings and facilities sector.
- A study of safety in the supply of energy.
- Preparation of an environmental report.

During the preparation of the PECQ, a series of instruments were applied that facilitated an in-depth study of energy performance of different sectors, as well as the integration of all the results of the sectoral analyses into a single tool. The key applications were as follows:

- **Geographic Information System (SIG):** a tool that makes it possible to link large databases with territorial coordinates to produce georeferenced databases that can represent maps or conduct territorial analysis.
- **Pollutant dispersion model:** this makes it possible to analyse air quality based on an emissions inventory by means of pollutant dispersion modelling and chemical reactions that may be generated in the field of study.
- **Overall analysis model of the city:** this makes it possible carry out an overall analysis of the city and of the typologies that comprise it from the perspective of energy and greenhouse gases.
- **Classification tool for projects and grouping scenarios:** this tool classifies, orders and groups the Plan's projects according to different criteria so as to define scenarios, make decisions about prioritising, visualise the environmental effects (be they positive or counter-productive) of the measures, and to model the applications of the projects over time.
- **Thermal simulation model for buildings:** a dynamic analysis of thermal demand and consumption of buildings that makes it possible - by means of building typologies that were originally defined in the PMEB and that represent the construction typologies that exist in Barcelona - to model energy consumption when certain measures are applied to buildings.
- **Economic model:** this allows for simulations of economic forecasts for Barcelona.
- **A tool for detecting and analysing vehicles that drive around the city:** categorises vehicles, according to technical and environmental criteria, that drive around the city using a system that reads registration plates and detects emissions from the vehicle's exhaust.

1.1.5 - THE PARTICIPATION PROCESS

The approach taken in the sessions

From the conceptualisation of the PECQ, it was considered that the participation of the general public, partners and sectors related to energy matters was of paramount importance. Thus, in 2008, a number of working sessions were proposed to define what the new Plan needed to cover. These areas set the course that led to the development of the Plan.

FIGURE 8 | **PARTICIPATORY SESSIONS CARRIED OUT**

So that the final version of the PECQ would also incorporate the points of view, suggestions, sensitivities and proposals from different partners and sectors associated with environmental and energy realities in the city, a participatory process was conducted during 2010 consisting of a number of sessions to present the results of the Plan and to gather together the contributions of the partners involved.

The working sessions were organised in two phases: a city working session, held in June, and a municipal working session, in October. The city working session involved eight sectoral working groups organised over one or two sessions, depending on the subject matter covered:

- G1 – Managing energy demand and performance.
- G2 – Energetic rehabilitation of buildings.
- G3 - Managing the quality of the energy supply.
- G4 – Renewable-energy generation and special schemes.
- G5 - Transport and energy.
- G6 – Climate change and air quality.
- G7 – Economic and legal analysis.
- G8 - Industry.
- Final joint session.

During the participatory sessions, participants' comments, contributions and suggestions were collected into two documents (the Final Report of the sessions and the Communication Report), which were used to define the PECQ's project proposals. Participants were invited depending on which issues were being discussed, although they were given the option of attending all the groups. A total of 268 people attended the meetings held at the Agenda 21 secretary's office.

Six web forums were organised for the online sessions. At each web forum, the strategic lines and action projects were presented, along with the proposals submitted by the participants at the face-to-face sessions. The nature of the forum was such that any visitor could see, in real time, the comments and stance of the other participants.

Alongside the sessions for individuals and organisations involved in the city, a municipal-level session was also held that was restricted to council administration bodies. A total of 86 people were invited.

FIGURE 9 | NUMBER OF PARTICIPANTS IN THE CITY WORKING GROUPS

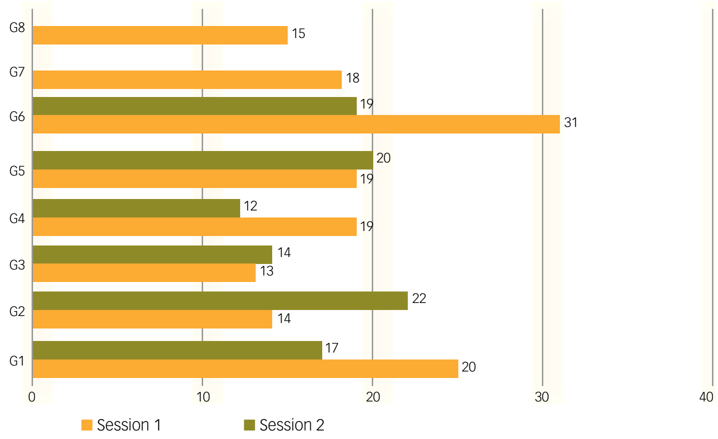
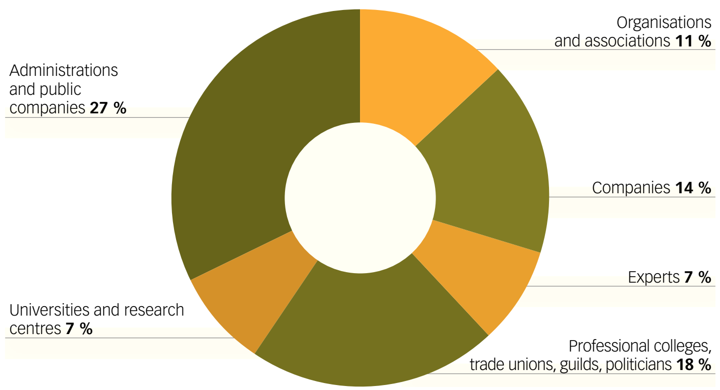


FIGURE 10 | SECTORS TO WHICH THEY BELONG



ORGANISATIONS INVITED TO THE MUNICIPAL SESSION

Districts

Public enterprises:

- Agència del Carmel
- BAGURSA
- Barcelona Regional
- BIMSA Barcelona Infraestructures Municipals
- BSM Barcelona Serveis Municipals
- Consorci Educació Barcelona CEB-IMEB
- Foment de Ciutat vella
- IBE - Institut Barcelona Esports
- ICUB- Institut de Cultura de Barcelona
- Institut Municipal de Mercats
- Pro-EIXAMPLE
- SPM Pro-Nou Barris sa PRONOVA

Departments and Municipal Sectors:

- Department of Social Action and Citizenship
- Department of Energy and Environmental Quality Services – Area of the Environment
- Department of Investment Services and Green Spaces – Area of the Environment
- Department of Water Cycle Services – Area of the Environment
- Department of Knowledge Management Services – Area of the Environment
- Department of Environmental Education Services – Area of the Environment
- Department of Waste Management and Cleaning Services – Area of the Environment
- Department of Prevention, Safety and Mobility
- Department of General Services and Territorial Coordination, Area of Human Resources and Organisation, Area of Education, Culture and Welfare
- Fire Prevention and Extinction and Safety Services
- Network of Energy Managers of the Energy Savings and Improvement Plan for Municipal Buildings

Conclusions of the process

The main conclusions of the final session of the process (at city level) were as follows:

1. **Ensure that local pollution is classified as a public health problem.** The direct relationship between air pollution and health is well known. Efforts are required to discover the local reality and to know how to adapt behaviour to that reality.
2. **Demonstrate the supra-environmental benefits of specific energy savings and renewable-energy installations.** In addition to the environmental benefits, renewable-energy installations have associated economic and social benefits in the form of savings and new jobs, as well as in terms of energy generation and a reduction in monopolistic tendencies, etc.
3. **Share reduction commitments with the general public (shared responsibility).** It will be impossible to meet sustainability objectives without the commitment of the public, i.e. with just political support. It is not a question of placing the responsibility on the general public but, rather, of emphasising the importance of their role whilst highlighting the responsibility taken on by other sectors that have, in the past, shown low levels of commitment.
4. **Publish periodic energy data and environmental indicators in order to raise awareness of the problem (right to information).** In general, there is a lack of information about energy consumption except for fuel economy data relating to vehicles. The standardisation of energy information will mean energy will be another variable when making decisions, as is the case with cars (miles per gallon) and refrigerators (simple information involving classification by letter). This energy education will become more important as the price of energy increases.
5. **Reinforce certain messages related to energy efficiency and renewable energies using the main communication tools.** Make use of the mainstream media to promote discussion about energy efficiency and renewable energy to reinforce the message.
6. **Place the emphasis on explaining the financial savings and that the maintenance of solar installations is an act of responsibility.** Lack of information leads to poor functioning of solar thermal installations. Experience has shown that simply providing information can lead to a user taking ownership of a system, discovering the benefits and deciding to carry out maintenance work.
7. **Provide examples of public installations and examples from the tertiary sector.** The third sector has a power to set an example to the public and must, therefore, be required to demonstrate the same awareness demanded of the public. The public administration, on the other hand, needs to be the first to stimulate this kind of behaviour.
8. **Set up a one-stop-shop for licences and permits.** For both construction projects and renewable-energy installations, simplifying administrative procedures via a single point of contact would reduce the associated costs of such procedures, which often have the effect of halting the project. In the case of renovations, simplifying procedures could avoid using unqualified personnel and be beneficial to well-qualified professionals, thus creating a communications space with the customer that produces the most efficient solutions.
9. **Positively incentivise good practices rather than apply penalties.** A policy of subsidies may encourage the public and property owners to opt for the best available solutions. Prioritise tax breaks as opposed to offering direct grants.

FIGURE 11 | DEGREE OF APPRAISAL OF THE PARTICIPATIVE PROCESS

▲ If the colour green indicates a good evaluation and yellow a good evaluation but with reservations, a high evaluation of the 12 items that participants were able to evaluate during the sessions was observed. The least-well evaluated item (referring to the interest aroused by the session objectives) received a 70% acceptance (between green and yellow)

With regard to the municipal session, the key aspects to come out were as follows:

- All the sectors were aware of the problems associated with the energy issue, although they cited a lack of both technological and instructive information that prevents them from exploiting their willingness to act.
- In general, the lack of benchmark information when it comes to energy issues generates dispersed data and complicates the gathering and processing of data.
- When designing new buildings, it is essential to take into consideration its future use so as not to oversize or undersize the systems.
- Audits and energy consumption checks are also needed, in particular in the case of buildings.
- In the case of vehicle fleets, there is considerable confusion about the environmental benefits/drawbacks of the various engine types. This means that those in charge of acquiring new vehicles are not in possession of all the necessary information in order to add environmental criteria to the purchase.

In general, all those who took part stressed the importance that this should be a plan for the whole Council, indeed, for the whole city, rather than just for the Department of the Environment.

1.2 - The context

1.2.1 - ENERGY AND CLIMATE CHANGE

Cities and climate change[3]

Cities are part of the problem of climate change insofar as they account for a significant proportion of emissions and energy consumption throughout the world. For this reason, they are a key part of the solution. The impacts of climate change are also felt in the cities. Generally speaking, city infrastructures are at risk given rising sea levels, fluctuations in the supply of drinking water and sea storms, whilst the population is subject to the combined effect of increasing global temperatures, the heat island effect, the consequent reduction in air quality, and heat waves.

In this context, cities, like regions and countries, essentially need to act on two fronts: mitigation and adaptation. The actions taken by local authorities are very important to manage climate change at both a local level (in that they improve the lives of the population), and at a global level, given that more than 60% of the world's population live in urban environments. In the European Union, 74% of the population live in urban areas, which account for 75% of energy consumption.

The importance of the issue can be seen in the number of international initiatives – for example, with regard to energy, the Covenant of Mayors within the European Union (which involves commitments to monitor emissions), a 20% reduction in emissions, and the International Council for Local Environmental Initiatives (ICLEI), an organisation made up of a large number of cities and regions throughout the world with the aim of working at local level to tackle sustainability issues, and that has a particularly active role in energy management and climate change.

Cities and their metropolitan areas constitute a strong link between town planning, the use of energy and GHGs. Urban density and spatial organisation are key factors that influence energy consumption, in particular in the areas of transport and buildings. Over the second half of the 20th century, and, in particular, over the last 20 years, the Barcelona Metropolitan Area has experienced significant urban and economic transformation that has, on the one hand, led to a larger urban area with new districts, and, on the other, a process of urban dispersion.

These two phenomena affect, in different ways, the conduct of the city with regard to climate change. However, in the cities, and, in Barcelona in particular, on account of its size and influence, these factors must be taken into account when managing climate change.

3. Josep Enric Llebot. Professor of Condensed Matter Physics, Department of Physics at the Autonomous University of Barcelona, and coordinator of the reports on Climate Change in Catalonia.

GREENHOUSE GASES

Carbon dioxide (CO_2) is the main greenhouse gas on account of its high level of concentration and is responsible for 55% of climate change. It can be produced during the complete combustion of hydrocarbons, during the oxidation of CO, or during the incomplete combustion of volatile organic compounds (VOCs). Vegetation absorbs CO_2 as a result of photosynthesis.

The potential of **methane** (CH_4) to heat the atmosphere is 25 times greater than that of CO_2; however, it is easier to reduce CH_4 emissions, given its shorter atmospheric lifetime (12 years). It also has the advantage that it can be used as a source of alternative energy and can be obtained, in particular, from controlled landfill, where it is produced during the breakdown of organic waste. Emissions of methane from transportation are, however, insignificant.

Nitrous oxide (N_2O) is the third of the main greenhouse gases. Whilst its concentration in the atmosphere is low, its global warming potential is 298 times that of CO_2.

Fluorohydrocarbons (HCFCs), **perfluorocarbons** (PFCs) and sulphur hexafluoride (SF_6) can also contribute to the greenhouse effect, although to a much lesser degree.

Temperature changes and precipitation in Barcelona

The warming of the atmosphere caused by the concentration of greenhouse gases in the atmosphere is a fact that is beyond doubt. The concentration of greenhouse gases in the atmosphere, especially CO_2, is increasing everywhere. The use of isotopic analysis confirms that a large part of this increase is due to human activity, in particular the use of fossil fuels. At a local level, measuring the environmental effects of this increase can be done from a number of different perspectives, although the most basic approach involves measuring changes in temperature and precipitation. In the Mediterranean area - and, therefore, in the Barcelona Metropolitan Area - it is also important to monitor extreme phenomena. Therefore, we will also conduct an analysis of what follows.

The results of the data series from the Fabra Observatory show that annual mean temperature has increased significantly from 1950 to today. The same analysis, although now applied to the annual mean of maximum and minimum temperatures, indicates that, during recent years, the trend of increasing temperatures is more apparent with regard to the maximum temperature than with the minimum. Seasonal analysis indicates that summer has experienced the most pronounced increase, whilst autumn is the only time of year that does not show a statistically significant trend.

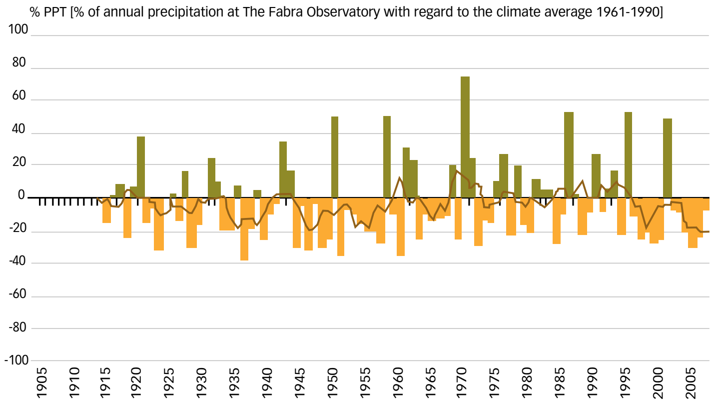
TABLE 1 | CHANGES IN TEMPERATURE AT THE FABRA OBSERVATORY IN BARCELONA EXPRESSED AS AN INCREASE PER DECADE

TEMPERATURE	MEAN	MAXIMUM	MINIMUM
Increase ºC	0,21	0,24	0,22

Source: Informació extreta de Martín-Vide 2010

The precipitation trend in Catalonia, in particular in Barcelona, does not show such a defined pattern as that relating to temperature, given the high seasonal variability. An analysis of annual and seasonal rainfall at the Fabra Observatory does not, for this reason, show a clear trend over the last century. Thus, any increases in rainfall, or low levels of rainfall, are not statistically significant and no conclusive trend can be observed. Nevertheless, measurements have been made that, in common with other observatories, would appear to indicate changes over the medium term: a slight increase in autumn and winter precipitation with lower precipitation in the summer.

FIGURE 12 | CHANGES IN ANNUAL PRECIPITATION ANOMALIES IN BARCELONA (1914-2008))



▲ The blue bars indicate positive percentages, i.e. years with abundant rainfall, whilst the orange bars represent dry years. The unbroken black curve shows the five-year moving average (taken from Martín Vide 2010 and the Meteorological Service of Catalonia. Annual Bulletin of Climate Indicators, 2008).

Climate projections for temperature changes and precipitation

- AT A CONTINENTAL LEVEL: THE MEDITERRANEAN REGION

The second report on climate change in Catalonia (Calbó et al. 2010) presents information about climate projections for the region classified as Europe and the Mediterranean. This area corresponds to the area defined as lying between the 30ºN and 75ºN parallels and the 10ºW and 40ºE meridians, sufficiently representative of what could take place in Catalonia.

As simulations depend on future emissions, a range of different scenarios have been designed at international level that aim to cover all future eventualities concerning demographic, economic and technological changes. The results that follow correspond to one of the intermediate scenarios with regard to changing emissions projections and the results relate to the end of the century (2080-2099).

- TEMPERATURE

According to the fourth Intergovernmental Panel on Climate Change (IPCC) report, for the area that includes Barcelona, the average temperature increase at the end of the century is expected to be 3.5ºC [3.0-4.0] - the first value is the mean, whilst the range in square brackets corresponds to the 25th and 75th percentiles.

The increase will be more pronounced in the summer (4.1ºC [3.7-5.0]) than in the winter (2.6ºC [2.5-3.3]). The analysis indicates that all the years at the end of the century – and most seasons—will be considered *"very warm"* compared with today's climate.

TABLE 2 | SUMMARY OF THE PROJECTIONS OF 21 MODELS FOR THE MEDITERRANEAN REGION, SCENARIO A1B TAKEN FROM THE FOURTH IPCC REPORT. DIFFERENCES IN TEMPERATURE (ºC) BETWEEN 2080-2099 AND 1980-1999

MONTHS	MIN	50TH PERCENTILE	MAX
December/January/February	1,7	2,6	4,6
March/April/May	2,0	3,2	4,5
June/July/August	2,7	4,1	6,5
September/October/November	2,3	3,3	5,2
Annual	2,2	3,5	5,1

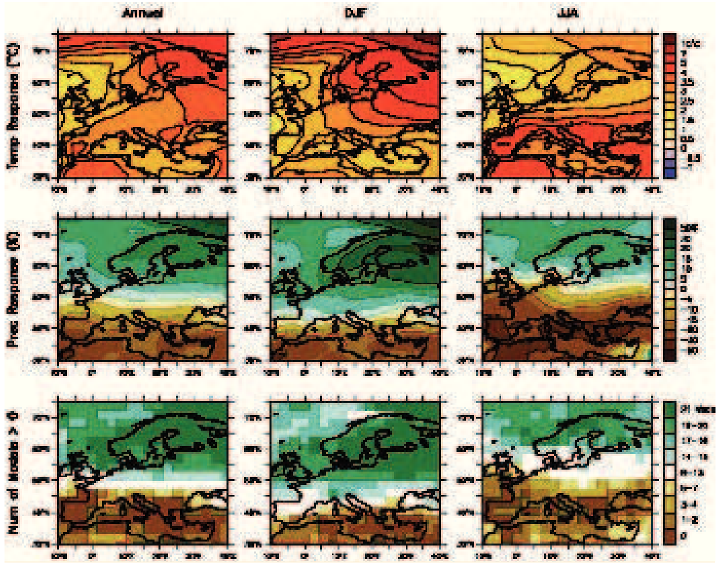
Source: Calbó et al. (2010)

To explain the spatial variability of these changes in temperature and precipitation, a number of maps of the Europe/Mediterranean region (see Figure 13) have been developed using the results of the global models used in the IPCC report. Maps are also given for the end of the century (2080-2099) compared with the end of the last century (1980-1999) and they are calculated as the mean of the variations given for all the models that were prepared. They are also given per annum and for the summer months (June, July and August) as well as for the winter months (December, January and February).

From an analysis of these maps, the following conclusions can be drawn:

- With regard to temperature, we can see that the average annual temperature for the Iberian Peninsula may increase by between 2.5ºC and a little over 3.5ºC. This is an estimate equivalent to that done for the whole of the globe and less than that for the rest of Europe.
- All of Catalonia lies within the line marking an increase of between 2.5ºC and 3ºC.
- On a seasonal basis, the situation is very differentiated. In winter, the pattern resembles that for the whole year, with increases in the Iberian Peninsula (and, in the Mediterranean in general) lower (2.5ºC) than those for north-eastern Europe. However, in summer, temperature increases for the Mediterranean area will clearly be higher than those in the rest of the continent, reaching values in excess of 4ºC in most of the Iberian Peninsula.

FIGURE 13 | CHANGES IN TEMPERATURE (TOP) AND PRECIPITATION (MIDDLE) IN EUROPE USING SIMULATIONS FROM 21 GLOBAL MODELS FOR THE A1B SCENARIO



▲ Differences between 2080-2099 and 1980-1999. From left to right, by annual mean, in winter and summer. Below, an evaluation of the uncertainty in projecting changes in precipitation, indicating the number of models that predict increases (Calbó et al., 2010).

- PRECIPITATION

The Mediterranean is one of the few regions in the world where estimates of overall lower precipitation (and also lower throughout all seasons of the year) are unanimous amongst the majority of global models. Using the projections drawn up to date, the following can be seen:

- Reductions in mean annual precipitation of 12% can be expected for the Mediterranean area.
- The decrease will be more pronounced in the summer (24%) than in winter (6%).
- Compared with today's climate, at the end of the century, almost half of the number of years would be considered as *"very dry"*.
- Situations that correspond to high rainfall in today's climate will be very rare.
- Around the year 2040, precipitation could fall by between 4% and 8%.
- The maps shown in Figure 12 reveal a marked latitudinal gradient in the area studied. In Catalonia, and, therefore, in Barcelona, precipitation is predicted to reduce by between 10% and 15% on an annual basis.
- In summer, the reduction in precipitation will be even more pronounced in the Iberian Peninsula (more than 30%, possibly as high as 50%).
- In winter, a large part of the Peninsula would come within an area of little change (0%-5%).
- There is a lack of homogeneity in the robustness of the precipitation projections. Most models agree that there will be lower precipitation in southern Europe, including the Iberian Peninsula. On the other hand, when it comes to winter, there are approximately the same number of models that predict lower rainfall as there are models that predict an increase: thus, with regard to winter, we can say that results are uncertain, or that the predicted changes are less significant.

TABLE 3 | CHANGES IN PRECIPITATION: SCENARIO A1B FOR THE MEDITERRANEAN AREA. PERCENTAGE DIFFERENCES IN PRECIPITATION BETWEEN 2080-2099 AND 1980-1999

MONTHS	MÍN	50TH PERCENTILE	MAX	WET SEASONS (%)	DRY SEASONS (%)
December/January/February	-16	-6	6	3	12
March/April/May	-24	-16	-2	1	31
June/July/August	-53	-24	-3	1	42
September/October/November	-29	-12	-2	1	21
Annual	**-27**	**-12**	**-4**	**0**	**46**

Summary of the projections from the 21 IPCC models (Calbó et al., 2010).

- OTHER BIOPHYSICAL SYSTEM VARIABLES OF INTEREST

Indicators of trends in climate extremes

The effects of climate change at a regional level cannot only be considered by an analysis of any trends observed in temperature or mean precipitation; they must also be considered in the light of verified changes in the frequency and intensity of different climatic extremes.

- The indicators show that, in Barcelona, there has been a reduction in the frequency and duration of cold periods and an increase in the frequency, intensity and duration of hot periods. With regard to precipitation, a slight increase in intensity has been observed.
- There is a significant positive trend in the number of days with precipitation measuring less than 10 mm between 1854 and 2005.
- No increase in the number of days with heavy rain has been detected.

TABLE 4 | CLIMATE INDICES APPLIED TO DAILY DATA TAKEN AT THE FABRA OBSERVATORY IN BARCELONA (1914-2008)

INDEX	FABRA OBSERVATORY
Frost day	Reduction
Summer's day	Increase
Tropical night	Increase
Length of growing season	Increase
Maximum annual maximum temperature	Increase
Maximum annual minimum temperature	Increase
Minimum annual maximum temperature	Increase
Minimum annual minimum temperature	Increase
Cold night	Reduction
Cold day	Reduction
Warm night	Increase
Warm day	Increase
Duration of hot spell	Increase
Duration of cold spell	Reduction
Annual temperature range	Increase
Simple index of precipitation intensity	Increase
Number of days with precipitation of >20 mm	---

▲ Only those indices that are statistically significant are shown. Meteorological Service of Catalonia. Annual Bulletin of Climate Indicators, 2008

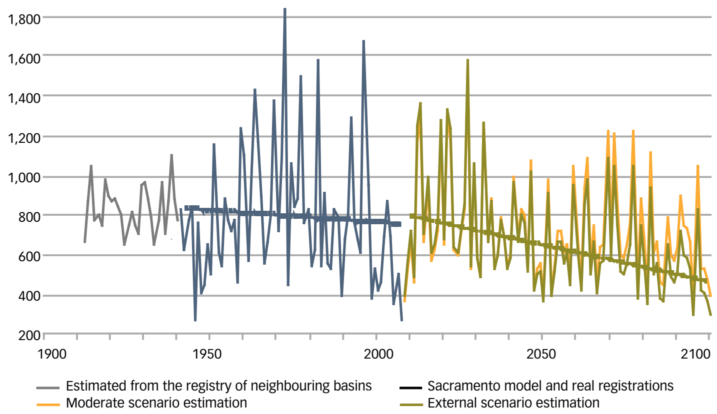
Droughts and water resources

In addition to the temperature and precipitation projections, an important element for the Metropolitan Area of Barcelona is the provision of water. Although this depends, to a large degree, on rainfall, it also depends on other factors related to the foreseeable increase in evapotranspiration and the increase in wooded areas at river headwaters.

A recent study on the supply of water showed the likely trend in annual contributions to the network of reservoirs connected to the Ter and Llobregat rivers (which supply the Barcelona Metropolitan Area) throughout the 21st century and compared with what was observed during the 20th century.

A downward trend appears likely, in particular during the second half of the 21st century. Naturally, this conclusion does not mean that the contribution of the rivers will be inferior every year, rather, that towards the middle of the 21st century, annual contributions will have a tendency to be lower than they were during the end of the 20th century, following a trend that cannot be ignored.

FIGURE 14 | HISTORIC CHANGES IN THE ANNUAL CONTRIBUTIONS TO RESERVOIRS SERVED BY THE TER AND LLOBREGAT RIVERS AND POSSIBLE CHANGES DURING THE 21ST CENTURY



Source: Manzano 2009

Heavy rain and flooding

Generally speaking, the risk of downpours and floods in Catalonia is along the coast, which means the Barcelona Metropolitan Area is also affected. From the climate indices calculated by the Meteorological Service of Catalonia in reference to the Fabra Observatory, the change in the maximum value for daily precipitation shows a positive, although statistically insignificant, trend. The maximum annual precipitation registered over 5 consecutive days was positive, although not significant, neither was the positive trend in the number of days in which rainfall exceeded 50 mm or days with very abundant precipitation, or the trend in total accumulated rainfall on days when daily rainfall exceeded the 95th percentile (very rainy days) and the 99th percentile (extremely rainy days).

Total annual precipitation divided by the number of days with more than 1 mm of rainfall, or the Simple Index of Daily Intensity, is the only index related to heavy rainfall that shows a positive trend that is statistically significant. Nevertheless, given that other indices relating to extreme precipitations have not shown, to date, any trend, it cannot be concluded that there is an increase in intense precipitations. Therefore, it cannot be stated that there is an increased risk of catastrophic flooding, given that such events are directly associated with climatic variations.

Strong winds

Traditionally, strong winds are meteorological events that result in more reports by the meteorological services on account of their repercussions in terms of damage and insurance claims. In Barcelona, they are also important because of how they are related to sea storms and how they affect the whole coast (beaches, etc.). Recently, more attention has also been paid to tornadoes, a phenomenon that has been well-known for many years in Catalonia, as can be seen in the number of names given to these spectacular meteorological events: bufaruts (strong wind), mànegues (whirlwinds), esclafits (cracks), tornados (tornadoes), fiblons (stings) and cap de fibló (water tornado). No predictions have been made about such atmospheric phenomena, although, from a purely speculative and qualitative point of view, it could be thought that an increase in air and sea temperature may lead to a greater frequency of tornadoes and wind storms.

With regard to sea storms, the more vigorous waves near Barcelona come from the east, corresponding to a wind run that creates the longest waves. Along the Catalan coast (and it would be logical to presume the same applies to the Barcelona coastline), there has been a trend towards a slight reduction in the number of severe storms, whilst there has been a slight increase in the number of moderate storms. The average duration of moderate storms, on the other hand, has remained constant, whilst severe storms are tending to last longer. Such trends are not statistically significant because they are linked to the fact that the sea level along the Barcelona coast has hardly changed over the last 16 years (Sánchez-Arcilla 2010).

Over the future medium term, no significant physical impacts are expected with regard to wind storms.

Heat waves and high temperatures

Heat waves and high temperatures are risks of an exclusively meteorological origin. They have acquired particular importance because they are linked to climate change. The definition of a heat wave is an event that lasts for at least three consecutive days and nights during which time maximum and minimum temperatures exceed the 90th-95th percentile for the values for the period from June to September. Although it may appear more likely that heat waves are more common inland, particularly taking into account that they are also associated with low humidity, in the Barcelona Metropolitan Area and in inhabited coastal areas in general, it is important not to underestimate the effect of such meteorological events, which can cause health problems - in particular for those at risk - when the humidity factor (and, thus, a stifling temperature) is added.

An analysis of maximum temperatures can be carried out using indices associated with and calculated using the data series from the Fabra Observatory in Barcelona (since 1913). Climate indices for the following indicate a statistically significant increase in heat waves: the number of summer days (maximum temperature 25ºC and above), the number of tropical nights (minimum temperature 20ºC and above), the maximum values for daily maximum temperatures and daily minimum temperatures, the percentage of days where the maximum and minimum are above the

90th percentile, the number of days in a year when there are at least 6 consecutive days where the maximum is above the 90th percentile, and the annual temperature range.

All the scenarios and models predict a future of high temperatures and heat waves. Furthermore, if we take into consideration that the heat island effect has an influence on this risk, we can see that this is one of the future risks relating to the impact of climate change that has an impact on the health of the population.

Quality of life and climate change

Cities consume most of the energy in the world and are, globally, the major source of greenhouse gas emissions. Actions at local level that could be carried out to tackle climate change can be classified in four categories:

- The city, as a consumer of energy in public buildings and in the facilities it manages, can set objectives and make commitments with regard to efficiency.
- The city, as a provider of services, has an influence on the development of infrastructures and needs to provide efficient services, whilst also taking into account climate change (transport, water, etc.).
- Given that the city regulates and prices its activities, this must have a bearing on reducing the impact of its activities, on cutting greenhouse gas emissions and on adapting to change.
- The city is the coordinating body in economic environments where it is one of a number of actors and, therefore, can help establish collaboration mechanisms with other sectors.

The contributions to climate change on the part of Barcelona can be classified in three areas, each of which has specific initiatives attached to it.

- Direct emissions of greenhouse gases: these include carbon dioxide, methane, nitrous oxide and halocarbons. The factors that contribute to emissions of these gases are transport, energy generation and conversion, waste and sewage treatment, and refrigeration systems, amongst others.
- Indirect emissions of greenhouse gases: these are caused by the activities of the city and of those who live there. Examples include emissions resulting from generating energy far from the point of consumption (cement, steel and glass production, etc.) that are used in civil infrastructures in the city.
- Changes in local atmospheric chemistry and in the city's surface albedo: an example of such processes is the generation of ozone associated with lighting causing light pollution and nitrous oxide in the city arising from transport and that also have a direct effect on health. The roofs of buildings and urban elements can affect the reflectivity of the city's surfaces (albedo), which has an influence on the heat island effect. The design of urban infrastructure also has an influence on the heat island effect.

Although the impact of cities on the global climate can be described as diverse and complex, greenhouse gas emissions from the continuous increase in energy consumption are the main one. In Barcelona, as in many other cities, emissions increase not so much as a result of industrial activity but as a result of energy consumption associated with lighting, heating/cooling public and private buildings and, above all, transport. Logically, cities are a very important and essential element when it comes to energy policies and, consequently, in reducing emissions.

International agreements

The first worldwide initiative to analyse the influence of human activity on the climate was held in Stockholm in 1972 during the United Nations Conference on the Human Environment. However, the Kyoto Protocol – an international agreement to make advances in reducing greenhouse gases - was not signed until 1997. The Kyoto Protocol was part of the United Nations Framework Convention on Climate Change (UNFCCC), signed at the Earth Summit in Rio de Janeiro in 1992.

The commitment of the Protocol is to reduce emissions by 5% (8% for the EU) compared with 1990 by, at the latest, 2008-2012, when the Protocol expires. Given, however, that the circumstances of each country are different, the specific commitment of Spain during that period is not to increase emissions by more than 15% compared with 1990.

In 2005, the Emissions Trading System came into being in the European Union (via Directive 2003/87/EC). The system establishes a means of trading greenhouse gas emission allowances in the EU with the aim of complying with the obligations derived from the Framework Convention on Climate Change and also from the Kyoto Protocol at European level. The market makes it possible to differentiate, within the emission inventories, emissions from sectors covered by the Directive from those arising from other sectors, known as *"diffuse sectors"* (transport and domestic).

Thus, the Directive makes the following distinction:

- Industrial sectors covered by the Directive: combustion, electricity generation, steel, ceramics, lime, cement, paper, oil refining and glass.
- Other emission sources, organised in the following groups (diffuse sectors): combustion plants of less than 20 MW, extraction and distribution of fuels, use of solvents, transport, waste, agriculture and other sources.

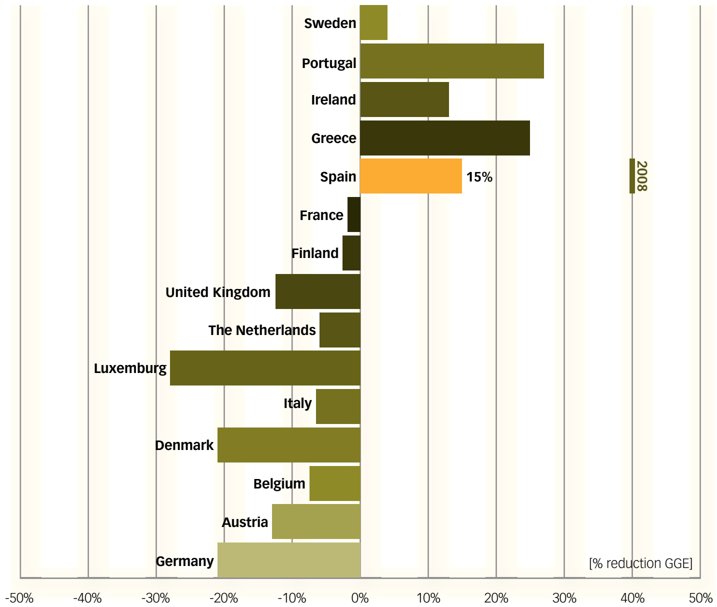
The same year, the members of the UNFCCC met in Montreal (Canada) to establish a working/monitoring group aimed at defining agreements beyond 2012.

In December 2007, in the framework of the 13th Earth Summit in Bali (Indonesia), participating countries re-orientated climate strategy in order to tackle climate change by means of a new, long-term agreement. During the working meetings held in Poznań in December 2008 and Barcelona in November 2009 (BCN Climate Change Talks), a work plan was approved that was supposed to be used to reach a key consensus agreement with new challenges to move towards mitigating climate change.

The process was due to have been completed at the Copenhagen Summit (the 15th Climate Change Conference - COP15). However, despite all the efforts made, no consensus agreement was reached, although it was established that there is a need to create transparent mechanisms with regard to the measurement and inventory of emissions, and reductions pledged by different countries.

The signature of a global agreement that sets new objectives for the post-Kyoto period (2012-2020) remains outstanding. Spain is currently one of the countries that is furthest away from complying with the Protocol, with emissions in 2008 exceeding 40% of their 1990 level.

FIGURE 15 | REDUCTION COMMITMENTS BY THE DIFFERENT COUNTRIES IN THE EUROPEAN UNION



National action strategies

With the aim of reducing the impact of the energy system on the climate, work has been carried out over recent years in Europe to improve energy efficiency and diversify energy sources towards systems that are less polluting or renewable. This has been accompanied by raising social awareness of the issues.

Public institutions, be they national, regional or local, play a fundamental role in consolidating a new energy culture (savings, efficiency, renewable energies and diversification). To adopt an efficient environmental and energy policy, the first step is to define the future scenario to be achieved and also to define the mechanisms that will be required to promote the strategy.

In the case of Spain and Catalonia, the following documents have been prepared over recent years to make progress in this line of action:

- **Revised version of the Energy Plan for Catalonia 2006-2015,** which establishes energy policies for Catalonia, the plan for renewable energies and energy supply.
- **The Spanish Climate Change and Clean Energy Strategy 2007-2012-2020,** which sets out the actions required to cut GHGs, establish flexible mechanisms for sustainable development, and boost the rational use of energy and energy efficiency along the lines of the **2008-2012 Action Plan of the Strategy for Energy Saving and Efficiency in Spain.**
- **The National Allocation Plan and the Spanish Strategy for Climate Change and Clean Energy** (Ministry of the Environment, 2007), aimed at reducing emissions in the diffuse sectors (i.e. those outside the scope of the Emissions Trading System Directive).
- **Spanish Strategy for Sustainable Mobility (Ministry of Development, 2008)** - a diagnosis of the transport system in Spain and proposed measures and initiatives to reduce consumption and emissions associated with the sector.
- **Catalan Plan to Mitigate Climate Change, 2008-2012,** which establishes the objective of reducing GHGs in Catalonia by 5.33 m tonnes during that period by means of a set of proposals arising from an intensive participative process.

PRINCIPAL IDEAS ABOUT CITIES AND CLIMATE CHANGE

- **Climate change represents a threat to urban infrastructures and to the quality of life of the population of Barcelona.**
  The impact of environmental changes associated with atmospheric warming - such as rising sea levels, heat waves and the heat island effect, sea storms and wind storms, and, directly, the increase in temperatures – raises the question of quality of life of the population and, in particular, leads to an increased risk of health problems for those population groups most at risk.
- **The way in which the city grows and functions is important with regard to climate change.**
  The use of energy and the energy production mix have an impact on greenhouse gas emissions. Urban density and city planning are key factors that affect energy consumption, in particular with regard to transport and construction. Therefore, projects such as @22 are flagship projects on account of their demonstrative character; but they are also important because of their impact as an absolute value.
- **How the public live in the city is very important with regard to emissions.**
  Emissions depend on lifestyles - i.e. it is not the city or urbanisation that are the sole determinants of greenhouse gas emissions.
- **Where the city's energy comes from is important.**
  The impact of energy consumption on greenhouse gas emissions depends not just on the amount of energy consumed but also on the source of the energy and how it has been generated. Barcelona has important electricity generation structures close to the city - a factor that increases efficiency. The activities of the city's Government related to the generation of renewable energy (especially solar) - something that makes the city an international benchmark – are moving forward in this regard.
- **Local actions must be coordinated with the CO_2 reduction objectives of other administrations.**
  The city's objectives must be coordinated. Therefore, actions must be carried out that are consistent with the emission reduction objectives, which are included in the Catalan Plan to Mitigate Climate Change 2008-2012, set by the Generalitat de Catalunya.
- **It is in the city where compromise between economic growth and environmental priorities needs to find an optimum balance.**
  Besides affecting the health of the population, pollution also affects competitiveness and the appeal of the city. However, more business activity involves higher energy consumption, more transport, and, therefore, more pollution. Barcelona's key infrastructures, such as the Port and Airport, contribute, although by increasing air and transport pollution.
- **Full policy evaluations need to be carried out.**
  Although it is difficult and complicated, an integrated evaluation of the effects of certain policies against climate change needs to be done.
- **Strategic plans for the city need to incorporate contributions and vulnerabilities to climate change.**
  Strategic planning cannot neglect to take into consideration the phenomenon of climate change, that it is, and will be, a factor during the years to come, both in terms of its impact and the repercussions of mitigating actions.
- **Use can be made of the flexibility mechanisms in the Kyoto Protocol.**
  In order to obtain emission reduction credits or sources of financing, it is possible to make use of clean-development mechanisms or joint implementation mechanisms. Barcelona is home to one of the most active companies in the field of emission allowance trading: Sendeco.
- **Barcelona is in a position to collaborate in creating efficient markets, products and services.**
  Municipal purchasing policies for goods and services that incorporate criteria related to managing climate change, integrating environmental objectives into the exploitation and planning of municipal services (for example, transport), and promoting initiatives or setting up *"green"* sector companies, in particular in the field of energy, which could lead to innovation and new jobs.

1.2.2 - ENERGY AND AIR QUALITY

Whilst gases such as CO_2, methane and nitrous oxide have a global environmental impact because they contribute to the greenhouse effect, other compounds have a local effect that mainly affect the health of the population by worsening the quality of the air, particularly in urban areas. These pollutants include nitrogen oxide (NO_x), carbon monoxide (CO), sulphur dioxide (SO_2), airborne particles and volatile organic compounds (VOCs). The burning of hydrocarbons such as petrol, particulate matter gas, liquefied petroleum gas, or natural gas, besides producing these compounds, facilitates their reaction between oxygen and nitrogen in the air and the emission of greenhouse gases.

Air quality in Barcelona and the metropolitan area

Air quality in Barcelona has been, since the end of the 1970s, one of the city's main environmental problems, as is the case with the majority of large conurbations throughout the world. Poor-quality air has a direct effect on human health.

The first control points to measure air quality in Barcelona were introduced in the 1980s (Parc de la Ciutadella in 1984 and Jardins Josep Trueta in 1988), mainly to measure the concentration of pollutants derived from the use of fuels such as coal and fuel oil (SO_2). The gasification of the city, combined with improvements in industrial processes and the renovation of electricity power stations has contributed, over recent years, to these fuels being replaced, leading to a decrease of SO_2 in the air.

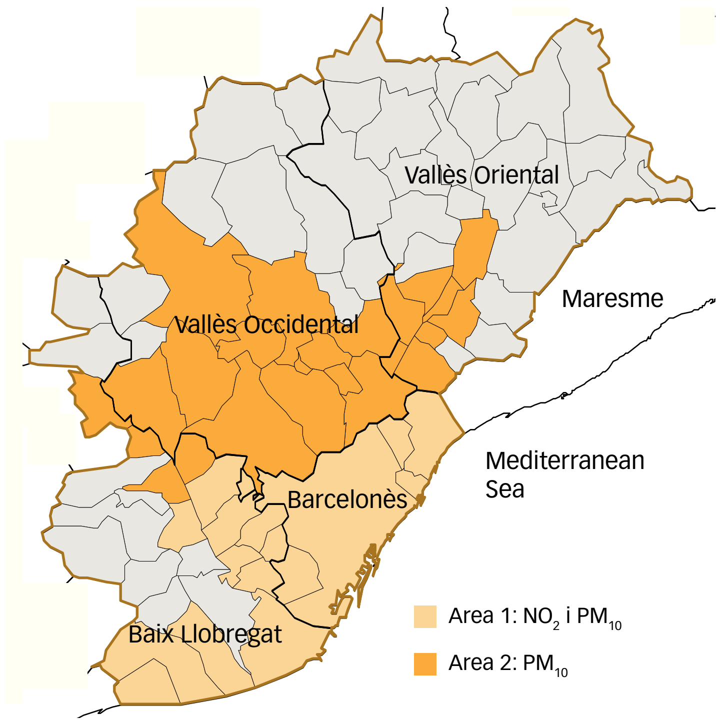
However, one of the main changes experienced by the city over the last 30 years, and that has influenced air quality, has been the increase in the number of private vehicles (aggravated by a larger proportion of diesel vehicles), which has led to increases, in particular, in concentrations of nitrous oxide and solid particles. Sulphur dioxide (SO_2) has continued to be a residual pollutant.

Barcelona, and other European cities (such as Paris, London, Berlin and Rotterdam), currently exceeds the limits for average annual concentrations of NO_x and PM_{10} (particles less than 10 μ) established by the EU to protect health (since 2010, the European limit for the highest annual average concentration is 40 $\mu g/m^3$ for NO_2 and PM_{10}.). This fact requires new strategies for action at all levels – from vehicle manufacturers to legislators – to improve air quality in the metropolitan areas.

Existing legislation (Law 22/1983, of 21 November, on the protection of the atmospheric environment) proposes guidelines to improve air quality. In this context, in 2006, Decree 226/2006 was passed declaring a number of towns in Barcelonès, Vallès Oriental, Vallès Occidental and Baix Llobregat as Special Protection Areas of the Atmospheric Environment. Later, in July 2007, the Department of the Environment and Housing approved an action plan to improve air quality in the areas declared as Special Protection Areas of the Atmospheric Environment. This new regulation established two areas: a NO_2 and PM_{10} protection area known as Area 1 to which Barcelona belongs and a PM_{10} protection known as Area 2.

Although the main aim of the Generatlitat of Catalonia's action plan is to reduce immissions (concentration of pollutants received by the population) of NO_2 and PM_{10} in order to bring them into line with the limits established under European legislation for 2010, the measures put forward will also contribute to reducing the emissions of greenhouse gases and, therefore, will help ensure that Catalonia complies with the Kyoto Protocol.

FIGURE 16 | SPECIAL PROTECTION AREAS OF THE ATMOSPHERIC ENVIRONMENT



One of the tools for evaluating air quality is the information supplied by the measurement stations that comprise the Air Pollution Surveillance and Control Network (XVPCA), set up under Law 22/1983, of 21 November on protecting the atmospheric environment. The network comprises a set of fixed and mobile stations to monitor, forecast and measure atmospheric pollution.

The evaluation of air quality via the XVPCA stations is carried out by comparing immission levels measured in Catalonia with the air quality objectives established by the EU. The XVPCA presents two kinds of immissions results in accordance with legal requirements: one provides information about immissions of contaminants as an annual average for NO_2, PM_{10} and $PM_{2.5}$, whilst the other measures hourly averages (for NO_2) or daily averages (for particulates), depending on the pollutant being measured, as the law establishes that, in a calendar year, a set number of hourly or daily limit values must not be exceeded.

The Public Health Agency has 11 active stations (automatic and manual) in Barcelona within the XVPCA measuring atmospheric pollutants. Amongst the fixed (automatic and manual) measuring stations and mobile units (that measure immisions at locations that are not covered by the fixed stations), there are a total of six that measure NO_X, ten that measure PM_{10} and three that measure $PM_{2.5}$.

GASES AND CONTAMINANTS WITH LOCAL EFFECTS

Nitrous oxide (NO_x) results from the reaction of oxygen and nitrogen in the air at high temperatures. Motor vehicles account for 65% of nitrous oxide emissions and it is calculated that, in urban areas, transport may represent between 60% and 70% of total emissions.

Airborne particles include unburned particles arising from the combustion of hydrocarbons or produced by the friction of vehicle tyres on asphalt, by the abrasion of the asphalt itself, by vehicle braking, by road works, or by the resuspension of dust on roadways. They can be classified as Total Suspended Particles (TSPs, which measure ≥ a 100 µm) or as Particulate Matter (PM), which include different categories, depending on their size. For example, PM_{10} applies to particles measuring less than 10µm in diameter, whilst $PM_{2.5}$ is used for particles with a diameter of less than 2.5µm. Particles smaller than PM_{10} affect human health on account of the fact that they can enter the respiratory system.

Carbon monoxide (CO) is produced by the incomplete combustion of fuel caused by a lack of oxygen. It is a pollutant that is characteristic of urban areas and is an indicator of traffic volume. Motor vehicles are responsible for 85% of carbon monoxide emissions in Catalonia.

Volatile organic compounds (VOCs), as with CO, are caused by the incomplete combustion of fuel. Transport represents approximately 50% of VOC emissions.

Sulphur dioxide (SO_2) is formed by the oxidation of sulphur in fuel; its emission is constant for each type of fuel. Fuels such as natural gas or liquefied petroleum gas (LPG) do not emit SO_2 because they do not contain sulphur. Emissions caused by transport, however, only represent 10% of total SO_2 emissions in Catalonia.

Tolerance thresholds

During 2008, Directive 2008/50/EC of the European Parliament and of the Council was approved regarding air quality and cleaner air for Europe. This Directive superseded previous legislation (Directive 96/62/EC, Directive 1999/30/EC, Directive 2000/69/EC, Directive 2002/3/EC and Decision 97/101/EC), with the exception of Directive 2004/107/EC relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons. The law also introduced the measurement of airborne particles measuring less than 2.5 µ ($PM_{2.5}$) in diameter and their related air quality objectives.

The legal limits established by the European Union are in line with studies carried out by the World Health Organisation (WHO).

- NO_2: epidemiological studies have shown that bronchitis symptoms in children with asthma increase with prolonged exposure to NO_2. In the same way, the reduced development of lung function is also associated with the concentrations of NO_2 that can currently be observed in cities in Europe and North America. Levels recommended by the WHO are the same as those set by the EU (annual average of 40 µg/m³ and an hourly average of 200 µg/m³).
- PM_{10} i $PM_{2.5}$: particulates affect more people than any other pollutant. They are mainly composed of sulphates, nitrates, ammonia, sodium chloride, carbon, mineral dust and water. They are formed by a complex mixture of liquid and solid particles of organic and inorganic substances in suspension. Chronic exposure to particulates increases the risk of cardiovascular and respiratory diseases and of lung cancer. The levels recommended by the WHO to obtain 95% confidence do not completely coincide with the levels set by the EU: the WHO establishes an annual average threshold of 20 µg/m³ for PM_{10} and 10 µg/m³ for $PM_{2.5}$, and a 24-hour average of 50 µg/m³ for PM_{10} and 25 µg/m³ for $PM_{2.5}$.

Action points in Barcelona

For many years now, Barcelona City Council, along with other public administrations, has been taking action to improve air quality by means of a number of different measures. The impact has, for the most part, been at an industrial level: modernisation of the waste-to-energy recovery facility, the conventional power stations at Besòs have been replaced with combined heat and power plants (lower emissions of pollutants). Furthermore, renewable energy has been given a boost by means of the Solar Thermal Ordinance, for example, and energy savings and energy efficiency have been promoted via projects included in the Barcelona Energy Improvement Plan.

However, it should be remembered that the main source of pollutants today is transport. In accordance with the Action Plan of the Generalitat de Catalunya associated with the Special Protection Areas of the Atmospheric Environment, land transport contributed to 40% of NO_x emissions and 52% of airborne particles and is the main source of both contaminants.

Attention must, however, be drawn to the efforts made to reduce emissions of pollutants: public transport has been enhanced with a fare integration system and the bus and metro networks have been improved, support has been given to promoting alternative means of transport with a more extensive network of cycle lanes and an improved Bicing (community bicycle) service. These measures have been accompanied by the introduction of parking regulations throughout many parts of the city.

However, more needs to be done – especially in the area of private transport – because Barcelona does not meet the air quality standards set by Europe.

TABLE 5 | IMMISSION LIMITS SET BY THE EU FROM 2010

POLLUTANT	SPECIFIC LIMIT VALUES	ANNUAL AVERAGE LIMIT VALUE
NO_2 (RD 1073/2002)	Hourly: 200 µg/m³ [Limit not to be exceeded: 18 times a year]	40 µg/m³ [42 µg/m³ el 2009]
PM_{10} (RD 1073/2002)	Daily (24 hour): 50 µg/m³ [Limit not to be exceeded: 35 times a year]	40 µg/m³
$PM_{2.5}$ (RD 2008/50/CE)	--	2010 objective: 25 µg/m³ 2015 limit: 25 µg/m³ 2020 limit: 20 µg/m³

FIGURE 17 | TRENDS IN POLLUTANT CONCENTRATIONS (NO_2)

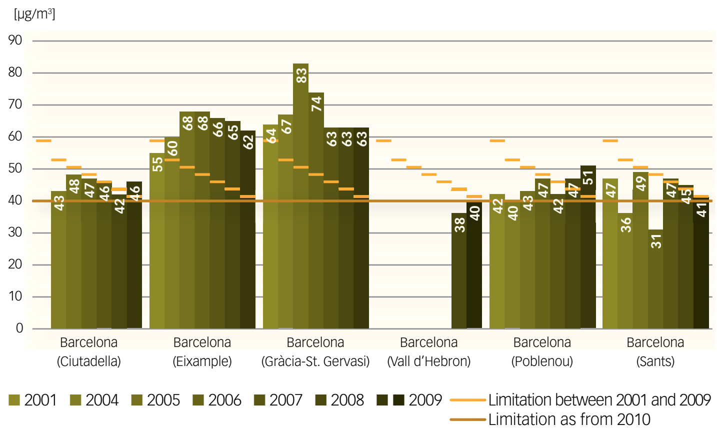
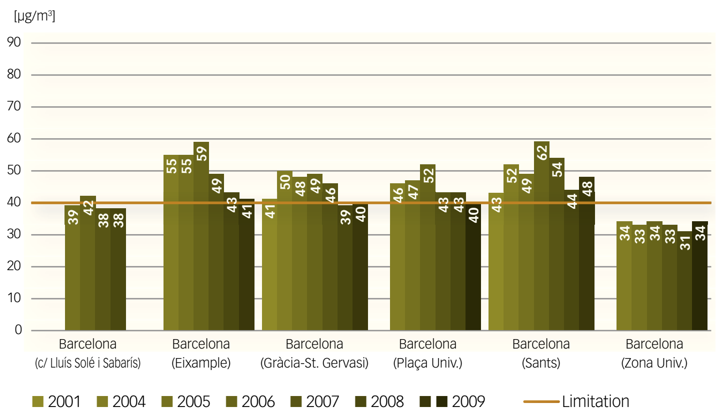


FIGURE 18 | TRENDS IN POLLUTANT CONCENTRATIONS (PM_{10})



Source: Direcció de Serveis de Vigilància Ambiental, Agència de Salut Pública i Departament de Medi Ambient. Ajuntament de Barcelona

▲ The horizontal line in the graphs represents the limit of 40 µg/m3 that must be met from 2010 onwards, according to the EU.

1.2.3 - THE REGULATORY FRAMEWORK FOR ENERGY

The PECQ was drawn up in the context of a complex regulatory framework relating to energy savings and efficiency, the use of renewable energies, the reduction of greenhouse gases and improvements in air quality. The laws and bylaws – at local, regional, state or European level – that are more relevant in these areas are listed below:

Building regulations

- **European Directive 2002/91CE**: Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings aims to promote energy efficiency in buildings via energy calculations and minimum efficiency requirements, energy certification, and periodic inspections of boilers and air conditioning systems.
- **Technical Building Code (CTE)**: approved by Royal Decree 314/2006, of 17 March, and partially modified by Royal Decree 1371/2007, of 19 October, this is the regulatory framework for setting basic quality requirements that buildings need to meet, including their installations, so as to satisfy basic requirements in terms of safety and habitability. A number of the basic requirements it covers are associated with fire safety, noise protection and energy savings.
- **Ecoefficiency Decree**: in addition to the CTE, in Catalonia, Decree 21/2006, of 14 February, regulates the adoption of environmental and ecoefficiency criteria in buildings with regard to water, waste, materials and construction systems.
- **Habitability Decree**: approved in 2009, this decree (55/2009) on the habitability of housing sets criteria related to sustainability and energy savings.
- **Barcelona Environmental Bylaw (OMA)**: since 2011, the OMA has included a section on energy that incorporates the Solar Thermal Ordinance in order to promote and regulate, by means of the local regulation, low-temperature solar energy facilities to produce hot water for

use in buildings (the regulation was modified in 2006), and the new photovoltaic bylaw, which regulates the incorporation of photovoltaic systems in new builds and refurbishments, depending on their use.

- **Royal Decree 1826/2009**: this law establishes minimum requirements in terms of energy efficiency for heat generators. Since 2010, it has been illegal to install boilers that do not meet the performance requirements specified in the decree. The decree also limits the interior temperature of occupied buildings that have air conditioning and that are used for administrative, commercial purposes or that are frequented by people.
- **Royal Decree 47/2007**: this decree is a fundamental law for the energy certification of new builds. Each building is assigned an energy efficiency class that ranges from A for the most efficient, to G for the least efficient.

Vehicles

- **Regulations governing vehicle emissions**: Directive 98/69/EC, governing passenger and light-use vehicles, and Directive 99/96/CE, affecting heavy-duty goods vehicles. A number of European directives, known as Euro directives, have come into force since 1992 to control vehicle emissions and to move progressively towards less-polluting vehicles that satisfy the requirements established in the directives about emission controls. The limit values for emissions and other considerations of a technical nature established by the regulation apply to all new vehicles that are mass produced and in use in a member State. It excludes vehicles that are already on the road or that are for export.
  Meeting the emissions levels established by Euro I (1992) and Euro II (1996) was achieved by making adjustments to traditional engines. The adaptation by manufacturers to new emissions standards took place over a gradual, two-stage process (Euro III and Euro IV), which required engines to be re-designed so as to offer greater environmental efficiency. Euro III brought about a significant reduction in emissions compared with previous periods and made it possible on a general level, as of 2001, to prepare the way for a definitive reduction in emissions, which took place in a second phase (Euro IV) from 2006 onwards. In some cases, the regulation makes it possible for emissions levels established by Euro IV to be met in two stages. It is planned that the second of these (called Euro V) will begin to be applied during the course of this Plan.
  To reduce CO_2 emissions, the European Union reached an agreement in 1998 with the European Automobile Manufacturers' Association (ACEA), which undertook to obtain average emissions of 140 gCO_2/km for vehicles sold in Europe by 2008. That was equivalent to a 25% reduction in CO_2 emissions from newly registered vehicles during 1995-2008. Furthermore, the ACEA committed itself to producing vehicles with average emissions of 120 g/km from 2000 and to review the agreement with the European Union in 2003.
- **Directive 2003/30/EC**: this Directive set a target of 5.75% biofuels use, calculated on the basis of energy content of all petrol and diesel sold for transport by 31 December 2010.
- **2009/28/EC, of 23 April 2009. Article 3:** this article stated that every Member State needs to ensure that the share of energy from renewable sources in the transport sector must amount to at least 10% of final energy consumption by 2020.
- **2009/28/CE, 23 April 2009. Article 17**: this article proposed a reduction in greenhouse gases produced from the use of biofuels and bioliquids by at least 50% from 1 January 2017. From 1 January 2018, this reduction will be increased to 60% for biofuels and bioliquids obtained in installations in which production started from 2017 onwards.
- **2009/28/CE, 23 April 2009. Article 5**: the amount of energy consumed by aviation should not exceed 6.18%, as a proportion of gross final energy consumption of that Member State.
- The Action Plan for Energy Saving and Efficiency, 2008-2011: this plan was approved by ministers at their Cabinet meeting on 1 August 2008. One of its targets was to reach a total of 1 million electric vehicles by 2014 throughout the state territory.

Energy efficiency measures

- **Commission Regulation (EC) No. 859/2009, of 18 September 2009, and Commission Regulation (EC) No. 244/2009, of 18 March 2009**: these regulations establish eco-design requirements for the sale of non-directional lamps for household and non-household use and when they are integrated into other products. Incandescent light bulbs will be progressively withdrawn (depending on wattage) up until 2012, when the regulation will be applied to all wattages.
- **Royal Decree 1890/2008, of 14 November:** this decree approved the Regulation on energy efficiency in external lighting systems and their technical instructions EA-01 to EA-07. The Regulation applies to the following installations of more than 1kW: exterior lighting (referred to in the ITC-BT 09), fountains (ITC-BT 09), and lighting for festivals and at Christmas (ITC-BT 34).
- **UNE 16001, energy management systems, requirements and guidance for use:** official European standard for energy management systems that has superseded all previous standards, including the old UNE 216301 standard.

Public buildings

- **The Action Plan for Energy Saving and Efficiency, 2008-2011, approved by ministers at their Cabinet meeting on 1 August 2008**: the Plan establishes compulsory targets set by the General Government Administration to reduce electricity consumption by 10% during the first half of 2009 compared with the same period in 2008. This level of saving is to be maintained during the current three-year period.

Waste

- The **main laws that govern waste management** are the Waste Framework Directive (Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008), Directive 1999/31/EC of the Council of 26 April 1999 (on the landfill of waste); Law 62/2003, of 30 December (on fiscal, administrative and social measures, and which amended aspects of Law 10/1998); the Integrated National Waste Plan 2008-2015 (PNIR) approved by the Cabinet on 26 December 2008; Catalan Law 6/1993, of 15 July (regulating waste), amended by Law 15/2003, of 13 July and by Law 9/2008, of 10 July; Implementing Decree 1/2009, of 21 July; and Law 8/2008, of 10 July (on financing waste management infrastructures and taxes on the disposal of waste).

Air pollution

- **Decree 152/2007,** of 10 July, approving the Action Plan to improve air quality in areas declared as Special Protection Areas of the Atmospheric Environment by means of Decree 226/2006, of 23 May. Together with Decree 203/2009, of 22 December, extending the action plan to improve air quality in the areas declared as Special Protection Areas of the Atmospheric Environment, approved by Decree 152/2007, of 10 July.
- **Decree 226/2006,** of 23 May, declaring a number of towns in Barcelonès, Vallès Oriental, Vallès Occidental and Baix Llobregat as Special Protection Areas of the Atmospheric Environment on account of particle levels and pollution in the form of nitrogen dioxide.
- **Royal Decree 1073/2002,** of 18 October, on assessing and managing environmental air quality with regard to sulphur dioxide, nitrogen dioxide, nitrous oxide, particles, lead, benzene and carbon monoxide, transposing directives 96/62/CE, 99/30/CE and 00/69/CE.
- **Decree 397/2006,** of 17 October, on the application of the system of trading of greenhouse gas emission allowances and for the regulation of the accreditation system for verifiers of greenhouse gas emission reports.

1.2.4 - INTERNATIONAL BENCHMARKS

When preparing its energy strategy, rather than acting in isolation from the rest of the world, Barcelona took into account policies carried out by other cities. As part of the preparation process for the PECQ, an international benchmarking study was carried out to look at the climate change and energy efficiency policies of other cities.

The following criteria were used to select the cities: those that have publicly expressed their concern for environmental and sustainability issues (e.g. cities that belong to ICLEI or that have a local Agenda 21), and cities that have, in the last five years, drawn up a plan or programme about energy, climate change or atmospheric quality.

The cities used for purposes of comparison were: London, Paris, Vienna, Stockholm, Fribourg, Amsterdam, New York and Sydney. In terms of the number of inhabitants and the surface area of the metropolitan areas, none of the cities were comparable with Barcelona. Vienna has a similar number of inhabitants, although it is much larger.

A wide diversity was found in the names of the plans. Nevertheless, two groups were identified: those that use a more traditional name and those that came up with a name, or even a slogan, that had more appeal from a communications point of view.

Most plans consider a long-term time frame as well as a short- or medium-term perspective. Stockholm has a very short-term plan (covering the years after the Plan was approved). The long term runs until 2050 (4 plans), followed by 2030 (2 plans). All intermediate time frames cover between 2010 and 2020, except for Stockholm (2005/2030).

From a conceptual point of view, all the plans shared the same objective (except Vienna), focusing on reducing CO_2 compared with a benchmark year. From a quantitative point of view, however, the plans are very different. Those that have set the highest reduction targets are Paris (75%), Sydney (70%), Stockholm (60-80%) and London (60%).

En general all the plans cover issues related to energy and climate change. Air quality is implicitly included in most of the plans (which incorporate measures to reduce air pollution), although only Fribourg and New York included it explicitly, dedicating a specific section to it. Most of the plans cover a wider scope. Other issues that are also covered are waste management, water management and tourism.

With regard to energy sources, most plans address petroleum and coal (except Fribourg), natural gas (except Stockholm) and biomass (except Stockholm and Sydney). Those energy sources given the most attention are solar thermal (7 plans), photovoltaic solar energy, wind energy and biofuels (6 plans). Hydroelectric energy (4 plans), tidal energy and geothermal energy (2 plans) are given less attention. Most of the plans (6) consider hydrogen as a valid alternative to current technology over the long term, based mainly on petroleum used in vehicle engines. With regard to electricity generation, all the cities are strongly committed to cogeneration, although only two consider self-generation.

Half the current plans include measures for capturing and storing CO_2 (by means of planting forests), although with, in all cases, complementary measures. Only the plans of Paris, New York and Sydney include measures to adapt to climate change.

All the action plans are mainly based on energy efficiency in buildings and measures related to transport and mobility. Most incorporate measures affecting buildings, in both the private sector (housing) and public sector (offices, equipment, housing and other municipal buildings) and also in the commercial sector (business premises).

TABLE 6 | PECQ – INTERNATIONAL BENCHMARKS

CITY (population)	AREAS COVERED		
	Energy	Climate	Air
LONDON (7,684,000) ▶ The London Plan - 2004	Yes	Yes	Yes
PARIS (2,167,000) ▶ Paris Climate Plan - 2007	Yes	Yes	No
VIENNA (1.670.300) ▶ Urban Energy Efficiency Programme - 2006	Yes	No	No
STOCKHOLM (798.700) ▶ Stockholm's Action Programme against Greenhouse Gas Emissions - 2003	Yes	No	No
AMSTERDAM (751.700) ▶ Amsterdam Climate Programme - 2007 ▶ Air Quality Plan - 2006	Yes	Yes	Yes
FRIBOURG (217.500) ▶ Freiburg Green City. Approaches to Sustainability - 2007 ▶ The Clean-Air Plan - 2006	Yes	Yes	Yes
NEW YORK (8.214.400) ▶ Plan NYC. A greener, greater New York - 2006	Yes	Yes	Yes
SYDNEY (164.500) ▶ Environmental Management Plan - 2007	Yes	Yes	No

DIAGNOSIS - Block 2 -

The City Programme

2.1 - Scope of analysis

2.1.1 - THE CONTEXT: THE CITY

Over recent years, cities and major conurbations have emerged as the greatest energy consumers worldwide. According to expert estimates, 75% of world energy is dedicated to maintaining the complex organisation of cities, which are now home to over 60% of its inhabitants.

When analysing the metabolism of cities, it should be remembered that they function systematically, similar to any natural ecosystem with regard to the demand for resources, water, energy and information and the generation of solid, liquid and gaseous waste. They are, however, much more complex as the human ability to concentrate activities and uses into a given area generally exceeds its capacity, i.e. the potential for meeting the needs and disposing of the waste products using their own resources. These flows therefore determine the city's relationship with the exterior.

Unfortunately, modern cities have a linear metabolism, and this is one of the chief causes of their heavy demand for resources, as the resources injected into the system are not used or re-utilised efficiently and neither are autochthonous, renewable resources rationally leveraged, especially energy resources.

Cities therefore have a great opportunity to become more efficient by making a more rational use of the resources available to them, with the advantages this brings as regards energy saving and reduction of their environmental impact, especially with regard to local emissions (pollution) and global emissions (climate change). To make progress in this area, action can be taken in different aspects such as reducing the demand for private vehicle transport, diversification of power production centres, the recovery of waste for energy purposes, the utilisation of renewable sources, improved efficiency of public buildings and facilities or the promotion of green urban areas, amongst others.

This new scenario also requires active involvement on the part of local government which should not act as simply another consumer in the energy market. Its role as a manager and legislator is necessary, naturally, but it must also play a major role in innovation, planning, education and promotion.

Cities therefore have a great opportunity to become more efficient by making a more rational use of the resources available to them, with the advantages this brings as regards energy saving and reduction of their environmental impact, especially with regard to local emissions (pollution) and global emissions (climate change)

2.1.2 - BARCELONA IN THE TERRITORY

Barcelona is located on the plain of the same name, which stretches from north to south, between the river basins of the Llobregat and the Besòs, and from east to west, between Serralada de Collserola and the sea. It covers a surface area of 101 km^2, and the maximum dimensions of the city are some 8 km between Collserola and the Port, and 9 km between Montjuïc and the river Besòs.

Barcelona's area of influence reaches beyond the administrative limits of the city. Over the past forty years, a characteristic phenomenon of large cities around the world has spread, metropolitinisation, such that Barcelona has become the centre of a large urban system in which the nearby towns, and even the outlying districts, have become a new geographic reality.

This has involved a process of extending the urban limits entailing major environmental implications for the territory. The current territorial references of Barcelona therefore depend on the area under consideration: The municipality itself, the Barcelonès district, Metropolitan area or the districts forming the Metropolitan Region. Thus, any planning or territorial decision taken or any socio-economic change to this territory as a whole clearly affects the functioning and dynamics of Barcelona.

This reality becomes especially clear in the planning and management of natural resources or services which have an obvious environmental element such as the collection and processing of waste, the drinking water supply and processing of waste water, the network of natural spaces or mobility and collective public transport. Energy, as occurs with natural systems, is the driver of this set of fundamental activities for the daily maintenance and operation of the urban system, signifying that the planning, arrangement and urbanisation of this set of elements which form the territory have a special effect on end consumption and the resulting generation of emissions.

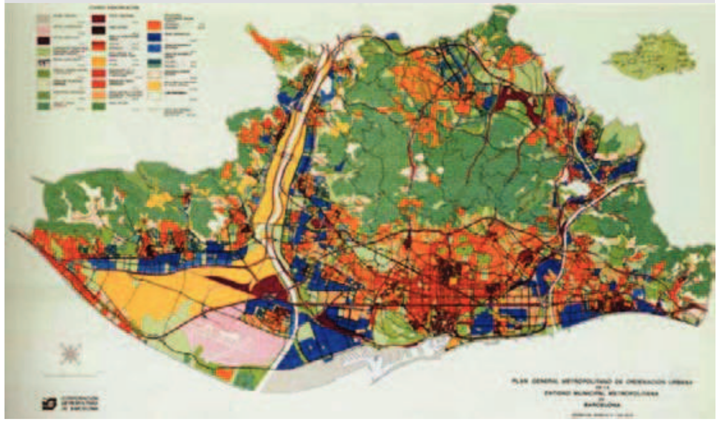
Although intervening in an existing city is a complex issue, new urban transformations and new districts must be designed and managed in keeping with sustainability criteria, so as to reduce the consumption of natural resources and energy and their socio-environmental impact. As regards energy, for example, over recent years Barcelona has adopted new criteria as regards the promotion of urban projects – in the development of districts such as Vallbona, for example-, and has introduced technological and regulatory innovations which have had a significant impact on the sector, such as district heating and cooling networks or the thermal solar Bylaw, amongst others.

Given this situation, it becomes necessary to move beyond these parameters and reflect on how urban evolution and territorial planning must address the issues of energy, climate change and air quality.

THE GENERAL METROPOLITAN PLAN

The town planning of Barcelona and twenty-six other municipalities in the Metropolitan area of Barcelona is governed by the general urban plan (PGM), a planning mechanism approved by the Provincial Urban Planning Committee of Barcelona on 14 July 1976.

The PGM is still in effect, despite having undergone numerous amendments over the years, to adapt it to the evolution of a complex territory in which urban centres and the economic activity coexist with natural spaces of great eco-systemic value.



2.1.3 - THE POPULATION

The population of Barcelona grew from just over half a million inhabitants at the beginning of the 20th century to over 1.9 million at the end of the Seventies, due to the strong migratory influx.

As from 1980 and over two decades, the city saw a demographic reversal. This phenomenon had not occurred at any time during the 20th century and was caused by two different factors which converged during this period: the slowdown in migratory processes of the city, due to the crisis; and the urban decentralisation process, of both production and residential activities, a feature which has progressively consolidated a metropolitan structure characterised by a considerable immobility.

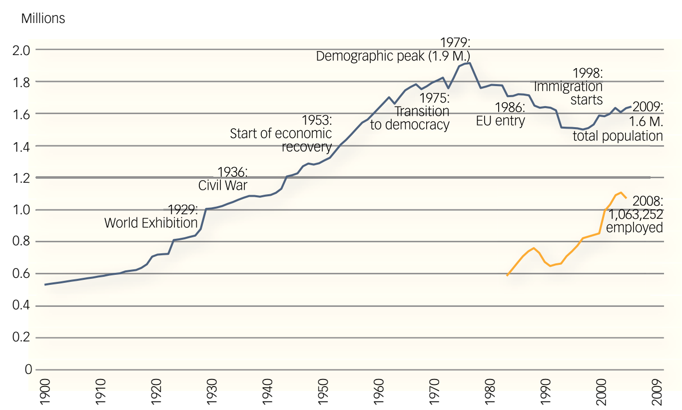
At the start of 2000 the situation changed again: this time in the form of foreign immigration, spurred on by the strong increase in the availability of employment, which coincided with a slight recovery in the birth rate. The number of jobs existing in the city reached its historical maximum in 2007 and the first semester of 2008, totalling 1.1 million, a figure which has progressively fallen with the economic crisis.

Barcelona currently has approximately 1.6 million inhabitants, well below the maximum figure of 1.9 million it achieved in 1979, but with a far higher residential stock due to the reduction in the average number of members per household. Thus, the population growth rate between 1992 and 1999 was negative (-1.15% a year), while between 1999 and 2009 it was slightly positive (0.8% a year), but falling short of the figures for 1992.

Throughout Catalonia and Spain, the long fall in the birth rate has transformed the traditional age pyramid for cities into an urn shaped figure, with the average age in Barcelona at 43.1, very high when compared to the Catalan average of 40.3, or the rest of the Metropolitan area of Barcelona which is approximately 39.

By age groups, 11.8% of the population in 2009 was between 0 and 14, 4.0% between 15 and 24, 63.9% between 25 and 64, and 20.3%, 65 or over. Nou Barris, Horta-Guinardó and Eixample are the districts with the highest percentage of elderly persons (65 or over), although this population sector accounts for over 19% in all districts, except Ciutat Vella. Sarrià-Sant Gervasi is the district with the most children (0 to 14) and Eixample that with the most young people (15 to 24).

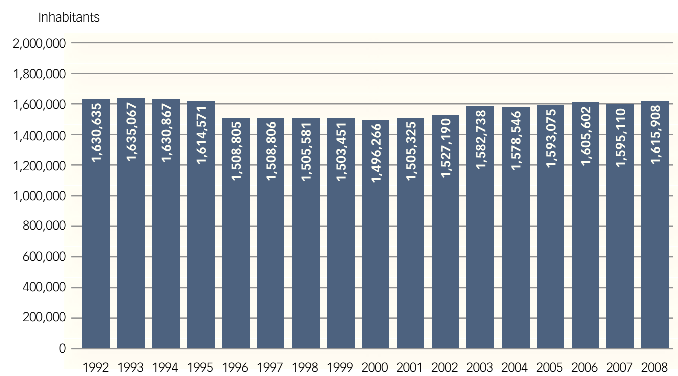
FIGURE 19 | EVOLUTION OF THE POPULATION OF BARCELONA (1900-2009)



Source: Department of Statistics Barcelona City Council

Immigration has increased and now accounts for 17% of the total population of the city, although the current economic situation is curbing this migratory process, especially from developing countries. All these factors make Barcelona a city of great social and multicultural complexity, with highly diversified patterns of insertion in the employment and housing markets. This is significant when evaluating the evolution of energy consumption in the city, as social attitudes towards energy is strongly linked to the intensity of society's energy consumption and each culture often interprets energy use in a different manner.

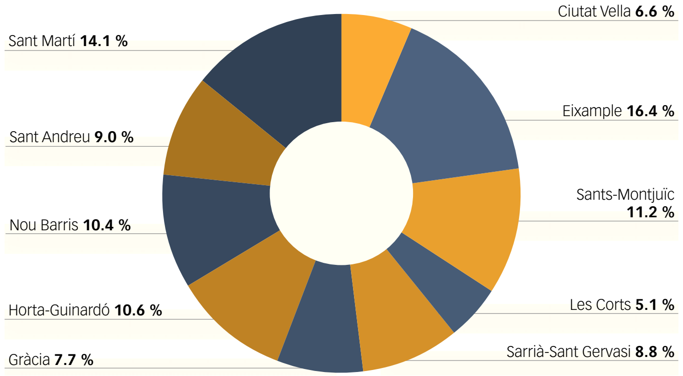
FIGURE 20 | EVOLUTION OF THE POPULATION OF BARCELONA (1992-2009)



Source: Department of Statistics Barcelona City Council

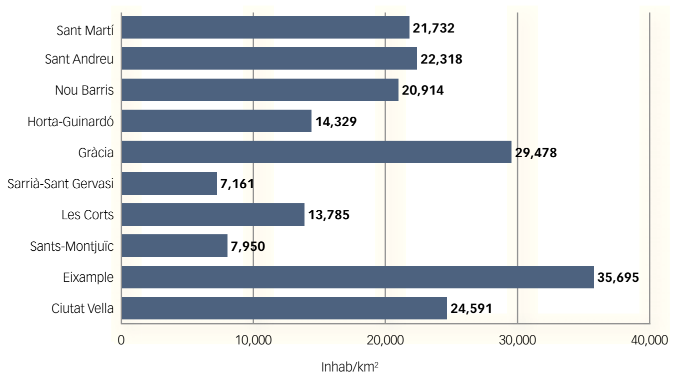
The highest population density is to be found in the districts of Eixample and Gràcia (35,695 and 29,478 inhab/km² respectively), while Sarrià-Sant Gervasi and Sants-Montjuïc are those with the least density (7,161 and 7,950 inhab/km² respectively).

FIGURE 21 | DISTRIBUTION OF THE POPULATION OF BARCELONA BY DISTRICT (2009)



Source: Department of Statistics Barcelona City Council

FIGURE 22 | DENSITY OF THE POPULATION BY DISTRICT (2009)



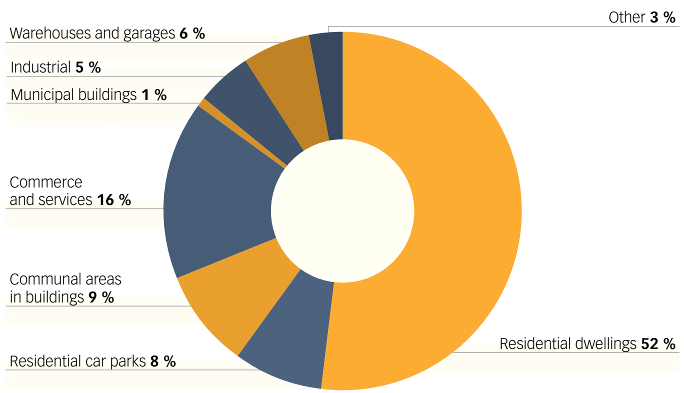
Source: Department of Statistics Barcelona City Council

2.1.4 - THE BUILDING STOCK

Throughout its history, the built-up land space area in Barcelona has seen sustained growth, with periods of heavy construction during transition periods, migratory waves or large urban growth.

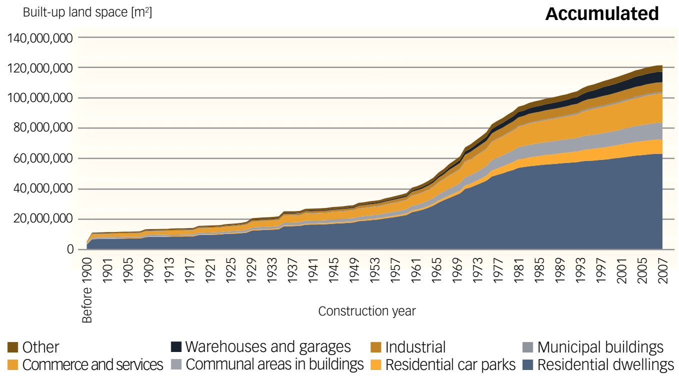
Over recent years, the rate of construction has been more moderate, with annual growth levels of under 1%. Despite this, between 1999 and 2007 approximately 3.2 million m² of new land space was built in Barcelona, totalling 121.35 million m². According to the land register database, over half is residential stock (62.7 million m²), followed by industrial facilities, garages and shops (22.9 million m²). There is also a notably large surface area dedicated to the business and office sector (8.2 and 6 million m² respectively).

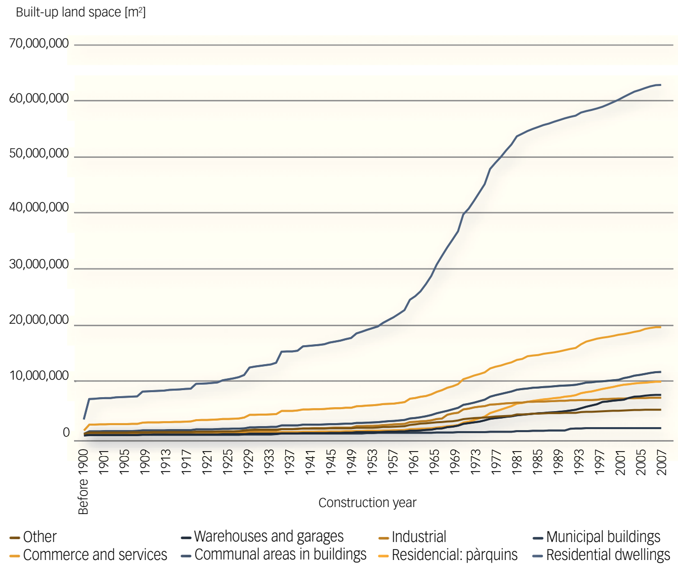
FIGURE 23 | LAND SPACE IN BARCELONA (2007)



Source: Barcelona Land Register

FIGURE 24 | EVOLUTION OF THE DISTRIBUTION OF BUILT UP LAND SPACE IN BARCELONA BY AGE (1900-2007)





▲ A comparison of the land space data by use in 1999 reveals that over recent years, Barcelona has seen a significant reduction in industrial land space (-0.8% a year) – accompanied by a move towards the services sector, with an increase in the office, commercial and sports stock. Chief amongst these is the business sector, with an annual growth of 4.5%, which rose from 5.7 million square metres in 1999 to 8.2 million in 2007. The residential sector also saw an increase of approximately 1.4 million square metres.

2.1.5 - ECONOMIC FACTORS

Barcelona is undergoing a long process of demographic and social change, which has also transformed its economic model. The city maintains a diversified economic structure, unlike other large urban centres, which have a critical dependence upon one or two subsectors. Barcelona is spearheading the deindustrialisation process of the Catalan economy.

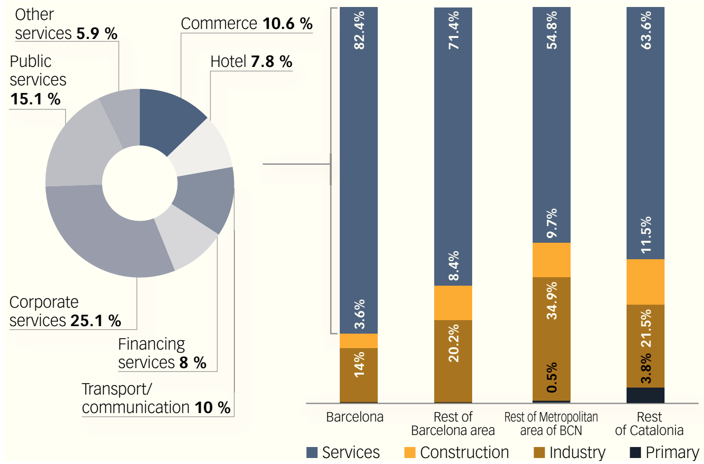
Economic sectors and labour market

Overall, corporate services account for 25% of the services sector and over 20% of the city's total economy. Hotel and commercial services also play a significant role in this service sector process. In quantitative terms, the growth of GDP in Barcelona averaged 2.5% between 2001 and 2008, totalling 63,100 m € in 2008. That year, GDP per capita was 38% higher than the average for Catalonia, an indication of how highly business is concentrated in the city.

Despite this growth in GDP, between 1991 and 2006 Barcelona saw its share of the Catalan economy fall, from 36.5% of GDP to 29.2%. This is a result of greater decentralisation of the production activity throughout Catalonia. It should be noted, however, that in 2008, when the change in the economic cycle was becoming apparent, the Barcelonès district was the most economically dynamic in Catalonia, with a growth of 1.7%, while the overall growth in Catalonia stood at 0.2%.

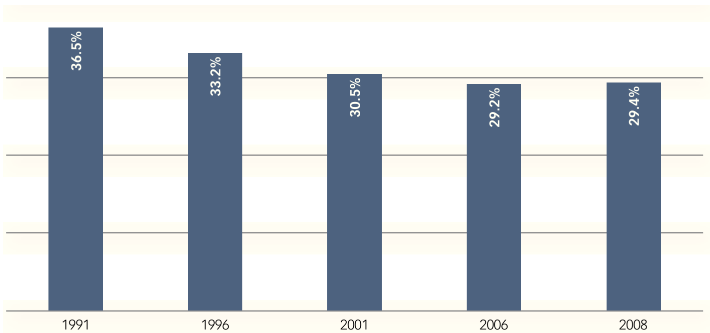
If we analyse the technological level of these industries and services, Barcelona is at the forefront in technology and knowledge, with an industrial fabric in which 10% of jobs have a high technological component and 41% a medium-high component. In the services sector there is also a trend towards specialisation, with 5% of services based on high technology and 43% on knowledge.

FIGURE 25 | DISTRIBUTION OF GDP OF BARCELONA IN CATALONIA (2008)



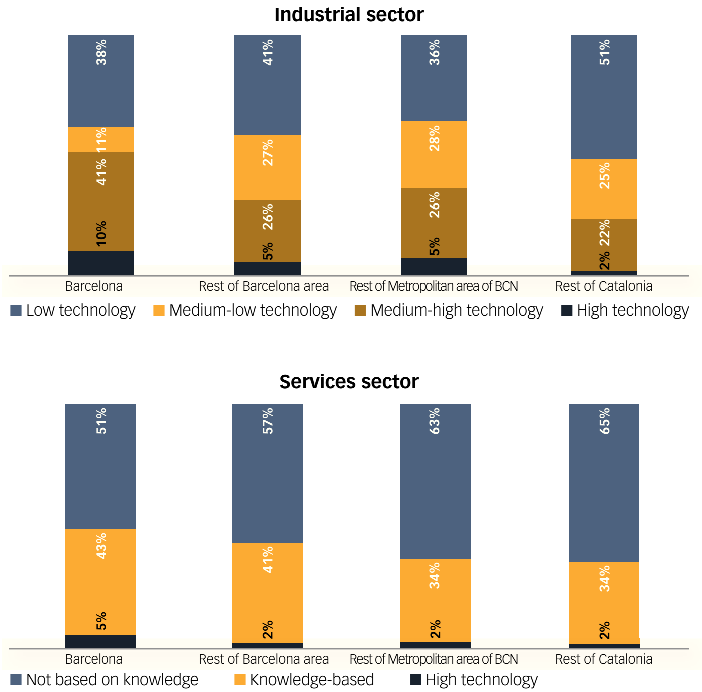
Source: Idescat and Caixa Catalunya

FIGURE 26 | EVOLUTION OF THE IMPORTANCE OF BARCELONA IN THE CATALAN ECONOMY (1991-2008)



Source: Caixa Catalunya

FIGURE 27 | **DISTRIBUTION OF CORPORATE ACTIVITIES BY TECHNOLOGICAL INTENSITY (2009)**

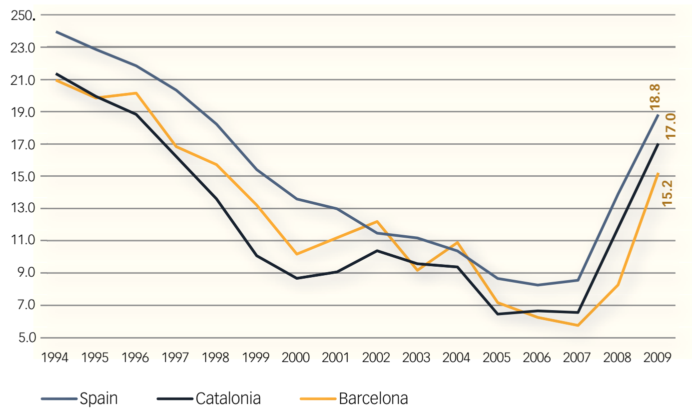


Source: Social Security

As regards the evolution of employment, the number of jobs in Barcelona grew by 15% between 2000 and 2007. Indeed, during the first quarter of 2008 it reached almost 1.1 million, although the current economic situation has led to a reduction of this figure, which at the end of 2009 stood at approximately 997,000.

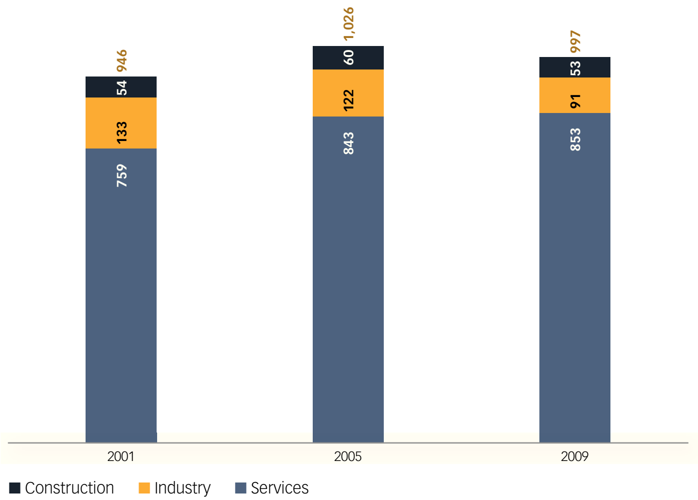
The unemployment rate totals 15% of the active population. This is lower than the Catalan average and falls far short of the figure for Spain as a whole. The long period of economic growth had led to a continued drop in the rate of unemployment, which stood at 5.8% in 2007, a level bordering on full employment.

FIGURE 28 | EVOLUTION OF THE UNEMPLOYMENT RATE OF BARCELONA (1994-2009)



Source: Labour Force Survey (EPA)

FIGURE 29 | EVOLUTION OF JOBS BY SECTORS IN BARCELONA (2001-2009)



Source: Social Security

The crisis, however, has triggered an increase in unemployment, similar to that of Catalonia and Spain. The transport sector, those sectors engaged in social, health and educational services and, overall, those associated with public services have seen the highest growth in unemployment. Another which has also seen a significant increase in unemployment is the hospitality sector, an indication of the growing importance of tourist activity in the city.

On the other hand, services for companies, which are the most important in the city's production structure and which had seen major growth until 2007, have been affected by the situation of the property sector. Commerce and personal services have been heavily affected by the fall in demand, while the financial system shows signs of difficulties and the need for re-structuring

FIGURE 30 | EVOLUTION OF INDUSTRIAL JOBS BY PRODUCTION SECTOR (2002/2009)

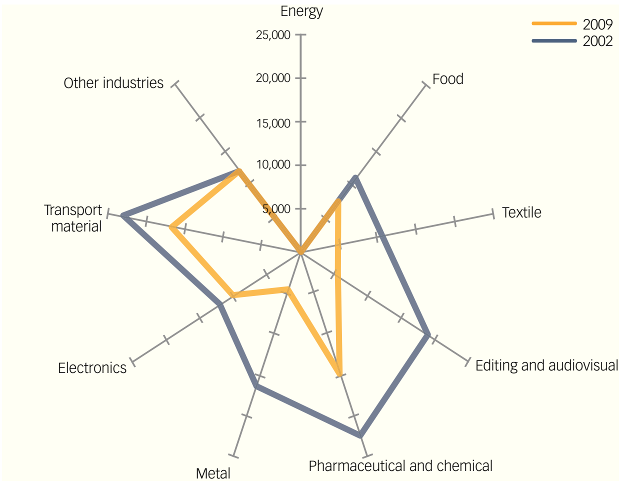
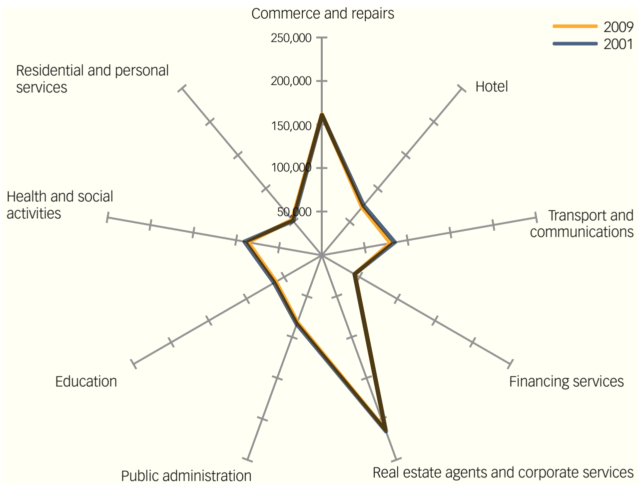


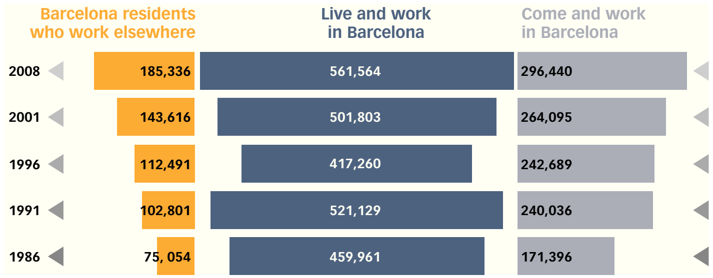
FIGURE 31 | EVOLUTION OF SERVICE INDUSTRY JOBS BY SECTOR (2002/2009)



Source: IDESCAT and Social Security

This evolution of the labour market has also entailed an increase in labour mobility. Barcelona attracts residents from other locations, but there are also a significant number of Barcelona residents who work outside the city. Commuter figures show a progressive growth in the number of journeys, with the resulting effect on energy consumption and transport-related emissions.

FIGURE 32 | EVOLUTION OF LABOUR MOBILITY IN BARCELONA (1986-2008)



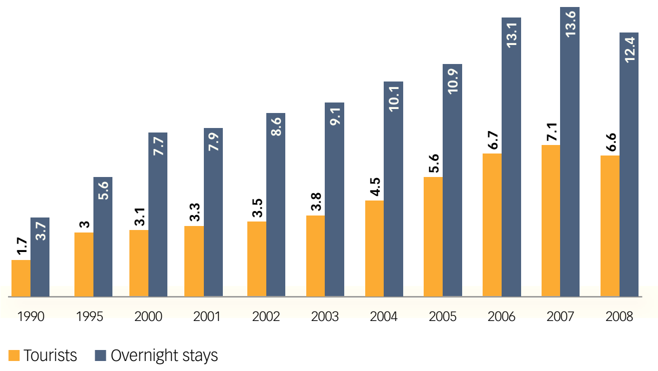
Source: IDESCAT

Tourist sector activity

The economic and socio-cultural context of recent years has fostered the international projection of the city. Furthermore, the development of transport infrastructures such as the Airport, the Port and the high-speed train have benefited tourist demand in Barcelona. The boom in low cost transport throughout Europe, the increase in the number of travellers worldwide and the popularisation of short stays in urban centres have also contributed to its success as a tourist destination.

An analysis of the evolution of the number of travellers and overnight stays in the city reveals that they have increased fourfold over the past twenty years, fomenting other forms of accommodation, such as apartments. Foreigners account for around 68% of overnight stays by tourists in Barcelona, 29% are visitors from the rest of Spain and the remaining 3% are from Catalonia.

FIGURE 33 | EVOLUTION OF THE NUMBER OF TRAVELLERS AND OVERNIGHT STAYS IN BARCELONA (1990-2008)

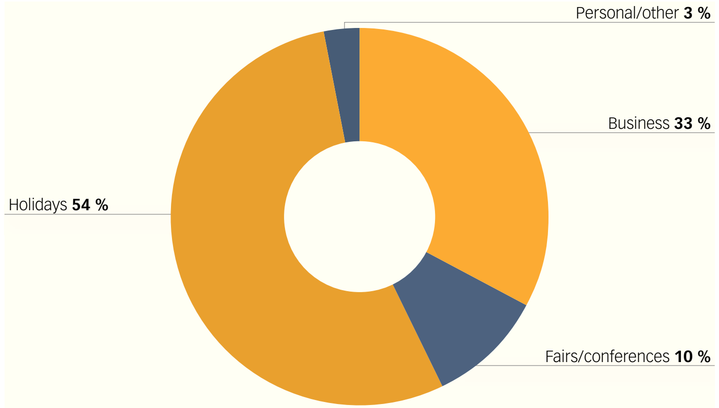


Source: Barcelona Tourist Dept

There is a notable balance between overnight stays for leisure purposes and for business and congresses. The former are strongly linked to an interest in architecture and cruises, while a large proportion of business tourism is linked to trade fairs. Barcelona ranks third in the world in the organisation of congresses, according to the ICCA (International Congress and Convention Association) and second by number of participants. Approximately 54% of tourists who stay at hotels in Barcelona are on holiday and 33% on business, without counting the travellers to trade fairs and congresses, who account for a further 10%.

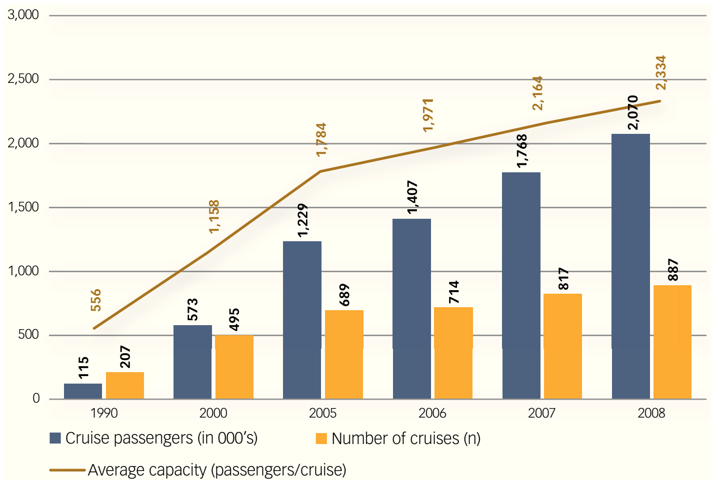
The emergence of new segments, such as cruises, has also led to an increase in the number of visitors, to such an extent that the Port of Barcelona currently ranks 5th in the world by number of cruises. This type of tourism does not involve accommodation in the city, but it brings a large expenditure in shops as this type of visitor has a medium/high level of income.

FIGURE 34 | REASON FOR TRAVELLING OF TOURISTS STAYING AT HOTELS IN BARCELONA (2008)



Source: Barcelona Tourist Dept.

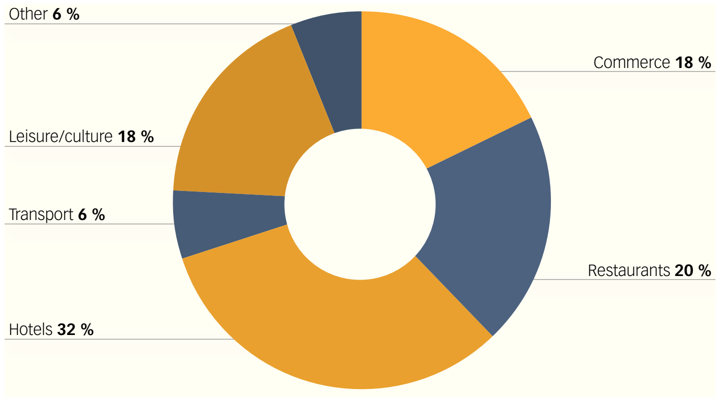
FIGURE 35 | EVOLUTION OF THE NUMBER OF CRUISES AND PASSENGERS AT THE PORT OF BARCELONA (1990-2008)



Source: Barcelona Tourist Dept.

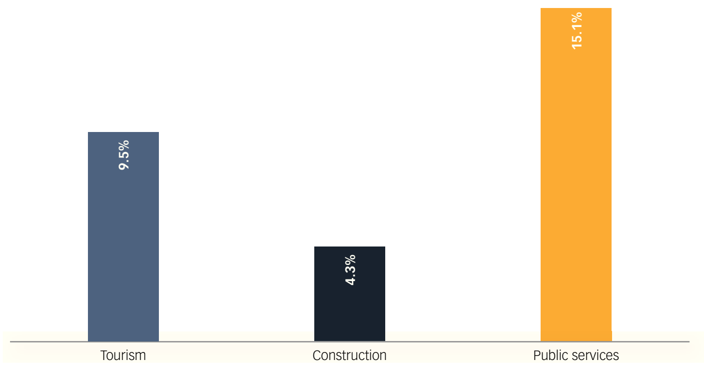
Tourism is a transversal activity which affects other production segments, with a strong impact on commerce and leisure and cultural activities, in addition to those related to the hospitality sector. Insofar as commerce offers services produced by other industrial sectors, the positive impact of tourism also encompasses other sectors. Overall, estimates indicate that tourist spending accounts for 9.5% of Barcelona's GDP[4], a sign of its importance for the city's economy.

FIGURE 36 | DISTRIBUTION OF TOURISM IN THE CITY'S PRODUCTION SECTORS (2008)



Source: IDESCAT

FIGURE 37 | THE IMPORTANCE OF TOURISM IN THE ECONOMY OF BARCELONA (2008)



4. In order to analyse the economic impact of tourism on Barcelona, various sectoral surveys have been used, such as those with visitors arriving in Catalonia and conducted by the Department of Innovation, University and Companies, nationwide data based on the Egatur survey, and those taken from the Tourist Activity Index prepared by the UAB.

2.1.6 - SOCIAL BEHAVIOUR

Research and defined variables

Individual attitudes and habits, and by extension social behaviour, have a great influence on the rational consumption of energy resources. For this reason, when drafting the Plan, a qualitative survey[5] was conducted to gain a detailed overview of the perception of energy based on a proposal for segmentation made during prior quantitative[6] surveys.

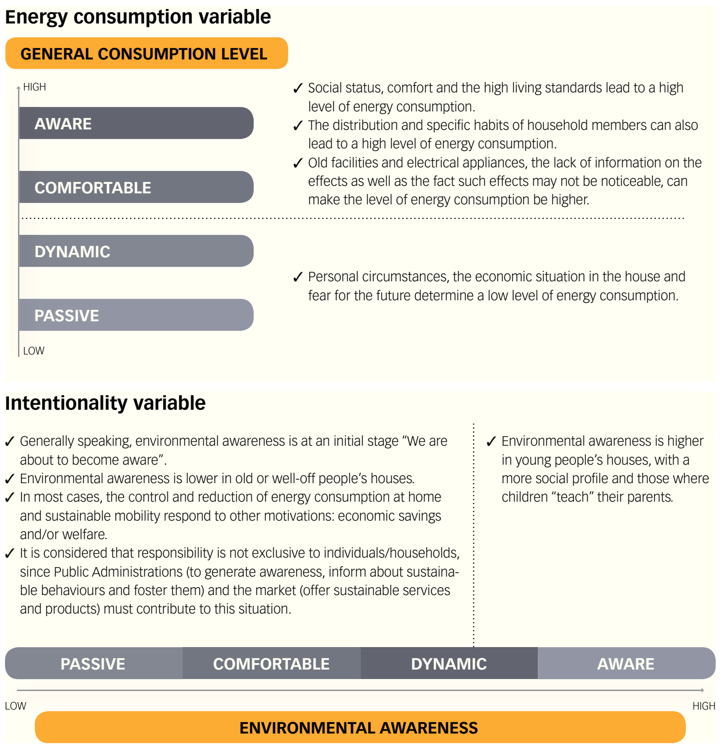
The survey identifies and characterises the energy-related needs, perceptions, motivations and attitudes of a varied public to energy use, their consumption habits and environmental awareness. Subsequently, a series of actions or projects are proposed which are designed to enhance energy consumption management from the viewpoint of social behaviour.

This initial statistical basis indicates that, in Spain, 86% of the public state they are concerned about climate change but this opinion is not reflected in their subsequent behaviour. A similar situation can be observed when analysing the European map of the population's attitudes with regard to environmental issues, for although Spain appears to be one of the countries with the highest environmental awareness, it is one of the least active.

Based on these statistical analyses, six different population segments are proposed, based on their behaviour towards rational energy use: aware, comfortable, dynamic, passive, anti-establishment and convinced. Of this proposed segmentation, it is estimated that the first four account for the majority (they represent 96% of the population), while the other two are less representative in the city as a whole. The study has focussed on the four segments considered the largest as they represent the majority of the population.

Two variables of social behaviour are used to classify the public in relation to their behaviour regarding energy use: Energy consumption variable and intentionality variable. The first variable segments the population according to their degree of energy consumption – and related articles and services -, identifying their spending capacity and predisposition to spend or consume. The second identifies those population segments according to their knowledge of environmental issues and their attitudes towards them.

FIGURE 38 | SOCIAL BEHAVIOUR VARIABLES STUDIED



5. Creafutur: Estudi de comportament social envers l'energia and Pla estratègic d'informació, educació i comunicació per a l'ús racional de l'energia. Barcelona, 2009. Commissioned by the Barcelona Energy Agency

6. Creafutur: Sostenibilitat i oportunitats de negoci i El futur del consumidor d'energia a la llar. Barcelona, 2008.

Ethnographic research

In order to define the measures and policies which can drive a change of perception towards energy use, the study centres on the citizens of Barcelona who have different economic and social circumstances. Based on a survey conducted in different dwellings, eight were chosen which are comparable to the characterisation proposed above:

- Single person's home in the Gothic Quarter
- Young family home in Diagonal Mar
- Home of an elderly couple without children in Les Corts
- Widow/er's home to the right of the Eixample
- Home of young couple in Nou Barris
- Single parent home in Sants-Montjuïc
- Home of retired persons to the left of the Eixample
- Home of North African immigrants in Ciutat Vella

The ethnographic study was conducted in two phases:

- **Diary of energy routines:** The families have recorded the energy consumption in their home (taking two working days and the weekend as a reference), and have prepared a photographic inventory of the appliances in their home.
- **Interview:** With the completed diary and data analysis, a team of experts has conducted a series of in-depth interviews to ascertain people's attitudes and behaviour in connection with energy consumption and saving in their home.

Thanks to the results of this research, certain priority actions have been established.

Population segments

Based on the segmentation produced by the aforementioned statistical studies and the ethnographic study, a characterisation has been formed of each segment:[7]:

- AWARE (29%)
  - Medium purchasing power, with a medium/high cultural level and aged between 25 and 35 (baby boom generation).
  - As a general rule, they are young families with small children, though there are also students sharing a flat or other young professionals.
  - The fundamental values and aspects are: Family, friendship, the future and improving the local environment (before the global environment).
  - High environmental awareness. They show interest in the environment and the impacts it receives and would like to learn more. They would readily change their lifestyle to be more *"sustainable"* if they knew how to and what the impact would be. They would also be prepared to pay more for clean energy.
  - Medium/high energy consumption. Those with medium consumption levels would like to consume less if they were taught how to.

- COMFORTABLE (27%)
  - Segment format per famílies amb un nivell adquisitiu mitjà/alt, i amb un nivell cultural molt variable.
  - Majoritàriament, són famílies amb pares de 40 a 60 anys, amb fills grans que tant poden viure a casa com estar emancipats.
  - S'estima que l'any 2020 aquest segment representarà només el 17% dels ciutadans[8].

- DYNAMIC (23%)
  - They have medium/high purchasing power with a medium/high cultural level.

7. It is significant that some of the definitions proposed by the authors were made in the scenario prior to the economic crisis and this may have altered certain associated behaviour, such as the inclusion of certain types of population in the segments.

8. Creafutur: *Sostenibilitat i oportunitats de negoci i El futur del consumidor d'energia a la llar.* Barcelona, 2008

- This segment includes persons aged between 35 and 55. They may be families of executives or middle management positions, young professionals (with academic studies and/or international work experience), who live alone, in a couple and with or without children.
- This segment is expected to grow to 27% over the next 10 years[9].
- They are aware of energy spending but do not find it high. The aspects they most appreciate are flexibility, communication, simplicity, originality and status, changing the world and enhancing the global sphere.
- Medium/high environmental awareness. They are aware of the impact of their lifestyle but will not sacrifice their standards of comfort.
- High energy consumption level. They are highly mobile and make intensive use of entertainment and communications devices.

• PASSIVE (17%)
- This segment is expected to shrink to 12% by the year 2020[10]. However, as it also includes retired persons and pensioners, it may tend to increase due to the ageing of the population.
- Segment comprising families with low purchasing power and variable cultural level. There are retired persons with low pensions, unemployed persons or families with an unemployed member, single parent families, young persons with few resources and certain collectives of immigrants.
- The persons in this segment are highly aware of what they pay, they consider that energy prices are high and would like to spend less. They therefore comprise the segment which consumes the least energy. The fundamental values and aspects are the family and the community, work, sacrifice and saving.
- Low environmental awareness. They would find it very difficult to change their current lifestyle if they do not obtain an economic benefit, in certain cases due more to reasons of economic precariousness rather than lack of willingness.

9. Creafutur: Sostenibilitat i oportunitats de negoci and El futur del consumidor d'energia a la llar. Barcelona, 2008.

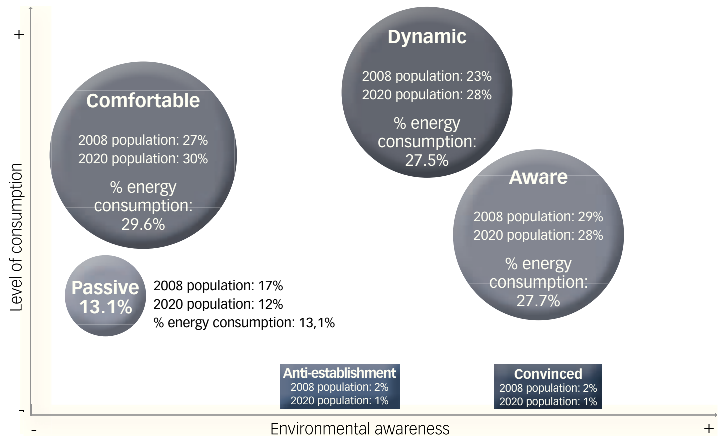
10. Creafutur: Sostenibilitat i oportunitats de negoci and El futur del consumidor d'energia a la llar. Barcelona, 2008.

- Low level of energy consumption, due basically to their low purchasing power (and to the fact they control their spending) and/or a relaxed lifestyle.

• ANTI-ESTABLISHMENT (2%) and CONVINCED (2%)

These have not been included in the subsequent ethnographic study as they account for a very small percentage of the total. Therefore, any measure centring on these two segments would have a low impact on the population as a whole.

FIGURE 39 | TABLE OF THE POSITIONING TOWARDS AWARENESS AND LEVEL OF ENERGY CONSUMPTION OF EACH SEGMENT



Priority actions

The behavioural study detects the need to act globally on the population as a whole, but it is the Comfortable and Dynamic segments which show the greatest potential for reducing their energy consumption.

The basic courses of action identified for these segments, which entail a series of measures and projects to be carried out over the coming years, are as follows:

- Provide information on the environmental impact of energy consumption in the housing sector. There is a percentage of the population that does not consider or is not aware that the housing sector and individual mobility have an environmental impact.
- Raise awareness of the economic saving to be gained from rational energy use, both by the individual (not wasting energy), and via technological efficiency. In schools, encourage the role of children to transmit environmental awareness and rational energy use to their parents.
- Provide greater support or personalised advisory services on energy/economic saving in the home. Equipment can be developed to monitor and display consumption in the home and incentivise the involvement of installation companies, home maintenance insurance companies, refurbishment professionals or energy suppliers to create the figure of the energy saving advisor.
- To raise environmental awareness a general demand for *"results feedback"* has been identified, to highlight poor practices and the effects that individual actions have on the environment. Therefore, educational work and feedback are necessary, with examples, experience, evidence and facts to increase people's awareness. It is also necessary to create user benchmarks (standard home consumption figures, etc.) for comparative purposes. There also exists a demand on the part of certain segments for economic incentives to drive good practices and saving.

2.1.7 - THE VEHICLE POPULATION

The analysis methodology

Road traffic energy consumption and its emissions must be determined indirectly. This is a differential feature compared to other sectors, the data for which can be established directly via the readings of power supply service connections.

To make this estimate as accurate as possible, it is necessary to obtain detailed information on the characteristics of the vehicles (horsepower, fuel, type, age), the average traffic speeds and kilometres covered by the vehicle population as a whole. The analysis of these data employs standard methodologies recognised by the European Union, such as the CORINAIR/COPERT[11] (CORe INventory AIR emissions).

The objectives of this methodology are to:

- Ascertain the exact composition of the vehicle population, via a representative sample.
- Improve energy consumption calculations and the resulting emissions of GHG associated with the vehicle population.
- Improve the calculation of local polluting emissions associated with the vehicle population.

The PECQ is clearly different to previous studies when characterising the vehicle population of Barcelona, as it is not based on the premise that the actual population is the same as that registered

The PECQ is clearly different to previous studies when characterising the vehicle population of Barcelona, as it is not based on the premise that the actual population is the same as that registered. A detailed study of the population vehicles in circulation has shown that it is clearly different to that registered; in particular, the former is more modern than that registered, an important factor when defining effective policies. The procedure used has made it possible to empirically measure the emissions from the exhaust pipes of the vehicles registered and compare these data with the CORINAIR emission factors.

11. Methodology created by the European Council of Ministers in 1985 within the framework of the EU programme to help member states to carry out emissions inventories. CORINAIR provides a full range of pollution emission factors by different types of vehicles, ages and horsepower. The latest version is from 2009.

The Plan identifies the road transport segments with the greatest emissions which provides a suitable viewpoint when deciding the strategy to be introduced as regards air quality and, above all, for fostering more effective measures by the relevant authorities.

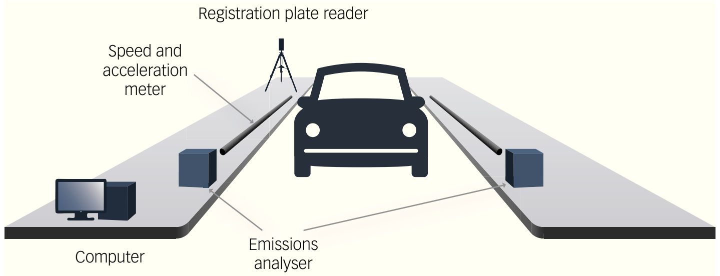
The inventory of the real vehicle emissions in Barcelona was carried out via a study made at 16 points throughout the city over thirty-two days in May and June 2009. Based on a reading of the registration plates of some 42,000 vehicles, the real vehicle population was determined with great accuracy together with their polluting emissions, as the registration data reveal the type of vehicle, its technical characteristics and the municipality of residence of its user.

The study also used a detection system for exhaust pipe emissions called RSD (Remote Sensing Device), which, unlike other onboard emissions detection systems is not intrusive, as it records the data without modifying the speed or acceleration of the vehicles. The RSD system subjects the vehicle to infrared and ultraviolet light to detect the vehicle's emissions instantly, and therefore thousands of recordings can be taken in just a few hours. The RSD was created in the USA and has been widely used since the nineties in countries such as Austria, Japan, the United Kingdom and Singapore, amongst others. The system has been verified and certified by the Automotive Research Bureau, California.

To improve the collection of information, speed and acceleration sensors were installed at various road points, making it possible to associate the emissions with the conditions under which each vehicle was circulating, as its dynamics are important when comparing data between vehicles. It should be noted that polluting emissions and particles (PM, CO, HC, NO_x) are measured in relative terms compared to CO_2 emissions. The recordings of the registration numbers were processed by the Traffic Authorities in order to obtain the specifications of each vehicle (type, horsepower, age, fuel and municipality of origin).

Of the sixteen points installed, fourteen recorded road traffic, while the other two were used to measure fleets of vehicles such as taxis and lorries entering the Port of Barcelona. In addition, the recordings of vehicles using the public municipal car parks and the entry toll to Mercabarna were analysed. The aim was to determine whether the type of vehicles using the car parks and the type of vans are representative of those in the city.

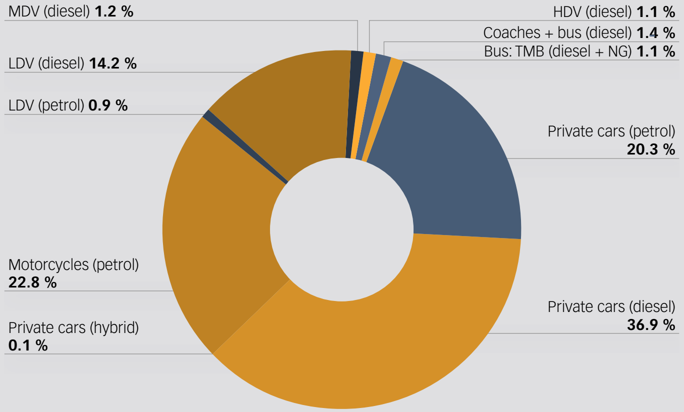
FIGURE 40 | RSD SYSTEM OPERATING SYSTEM



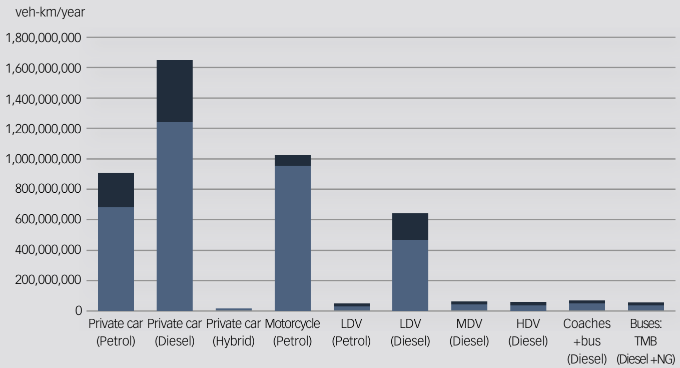
THE PROFILE OF THE VEHICLES

- The most common type of vehicle is diesel cars (including taxis), which account for 36.9% of the traffic in the city and the ring roads.
- Petrol cars account for 20.3% of the 4.439 million veh-km covered in 2008.
- The percentage of motorcycles and mopeds was 22.8%.
- 14.2% of the traffic were diesel vans (Light Duty Vehicles or LDV: with a maximum authorised weight of under 3.5 t.)
- These four segments accounted for 94.2% of total road traffic.

FIGURE 41 | DISTRIBUTION OF ROAD TRAFFIC IN BARCELONA AND RING ROADS, BY TYPE OF VEHICLE (2008)



Type	City veh-km/year (2008)	Ring Roads veh-km/year (2008)	City + Ring Roads veh-km/year (2008)
Private car (Petrol)	679.249.493	219.942.316	899.191.809
Private car (Diesel)	1.236.854.185	400.495.809	1.637.349.994
Private car (Hybrid)	3.962.371	1.283.024	5.245.395
Motorcycle (Petrol)	949.525.520	62.235.838	1.011.761.364
LDV (Petrol)	29.923.962	10.711.511	40.635.473
LDV (Diesel)	464.690.181	166.339.397	631.029.578
MDV (Diesel)	40.787.069	14.600.043	55.387.112
HDV (Diesel)	36.374.250	13.020.441	49.394.691
Coaches +bus (Diesel)	49.622.009	11.760.981	61.382.990
Buses: TMB (Diesel + NG)	38.622.700	9.154.020	47.776.720
Total	**3.529.611.742**	**909.543.378**	**4.439.155.126**



- AVERAGE VEHICLE AGE

The characterisation of the vehicle population performed within the framework of the PECQ revealed that the average age of the vehicles circulating in the city was 5.7 years. If we compare the population registered in Barcelona and that in circulation, the following results are obtained:

- 52% of the vehicles in circulation in the city are from outside Barcelona.
- The average age of the population of passenger vehicles (5.53 years) is lower than that of the registered population (9.13 years), indicating that probably the oldest vehicles circulate less than the newer vehicles (drivers who circulate more usually renew their car earlier).
- This difference is greater in the case of pre-EURO vehicles – both diesel and petrol-, as the registered population has over 20% of pre-EURO cars, while the pre-EURO vehicles account for just 1.8% of cars.
- The average age of taxis is 3.4 years, and that of lorries entering the Port of Barcelona, 6.5 years.

An age classification of the vehicles by type of fuel shows that petrol driven vehicles are older than diesel versions, with an average of 7.58 years. This is probably due to private users or companies who prefer to acquire diesel vehicles with the intention of using them more frequently, and also the lower cost of the technology, making them more affordable. i.e., these are vehicles which generally cover more kilometres than petrol cars, meaning that they reach the end of their useful life or depreciation earlier.

FIGURE 42 | AVERAGE AGE OF VEHICLES IN CIRCULATION IN BARCELONA (2008)

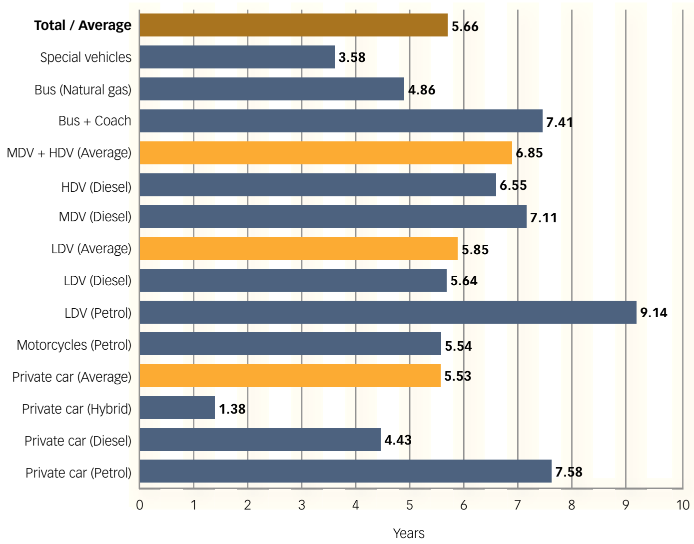


FIGURE 43 | AVERAGE AGE OF TAXIS IN CIRCULATION IN BARCELONA (2008)

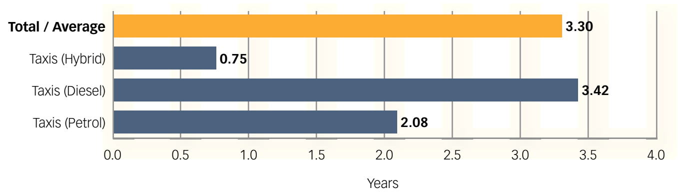
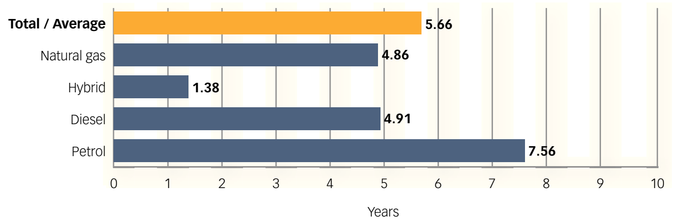


FIGURE 44 | AVERAGE AGE OF THE VEHICLES IN CIRCULATION IN BARCELONA, BY TYPE OF FUEL 2008 (2008)



According to the EURO[12] classification, 67.2% of traffic comprises EURO IV and EURO III vehicles. Generally speaking, they are vehicles manufactured in 2000 or later (except in the case of motorcycles, which have been subject to the EURO III standard since 2006). 39.2% are EURO IV vehicles which came into circulation in 2005 or later (except motorcycles which currently have no EURO IV classification, as the latest applicable standard is the EURO III). 28% are EURO III, vehicles manufactured between 2000 and 2004 (except in the case of motorcycles, to which EURO III has been applicable since 2006). EURO II vehicles account for 13.6% of traffic, the EURO I, 6.3% and the pre-EURO, 12.5%. The EURO V was still testimonial in 2009, with just 0.4%, as that year it was only applicable to buses and lorries, and not to passenger cars, vans or motorcycles.

12. European standard on local pollutants (NO_x, HC, CO and particles) which regulates the acceptable limits for new vehicle exhaust gas emissions sold in the member states of the European Union. The EURO I standard is the oldest –and therefore the least restrictive; previously there were the pre-EURO- standards, while the EURO V and future EURO VI are the most restrictive, as they require lesser polluting emissions per kilometre. Measurements are made according to a standard driving cycle defined by Europe.

FIGURE 45 | DISTRIBUTION OF VEHICLES IN CIRCULATION IN BARCELONA AND THE RING ROADS BY EURO CLASSIFICATION (2008)

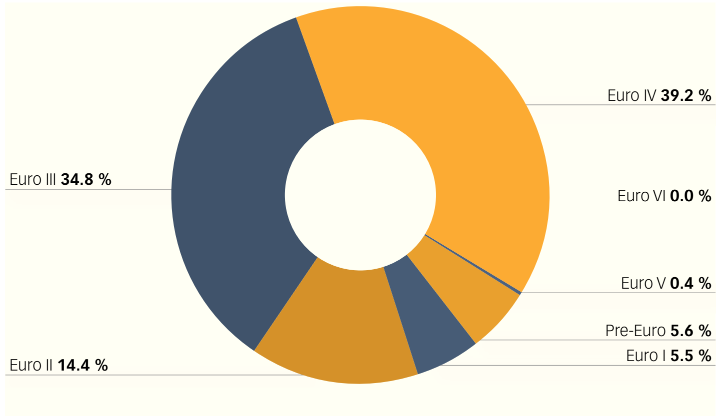
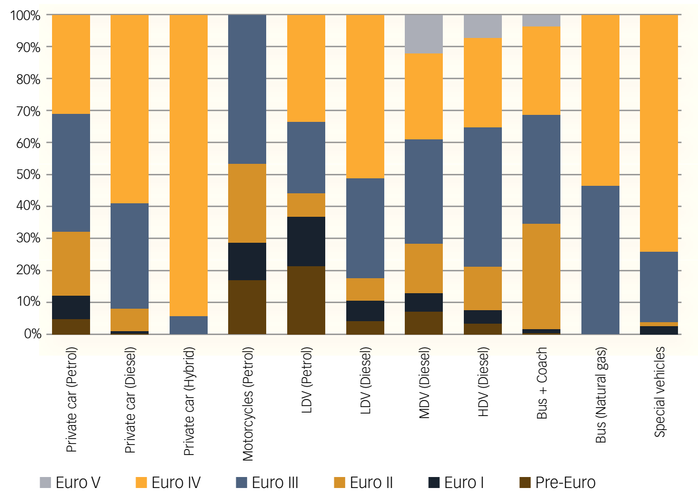


FIGURE 46 | CLASSIFICATION OF VEHICLES IN CIRCULATION IN BARCELONA AND THE RING ROADS AS PER THE EURO STANDARD BY TYPE OF VEHICLE (2008)

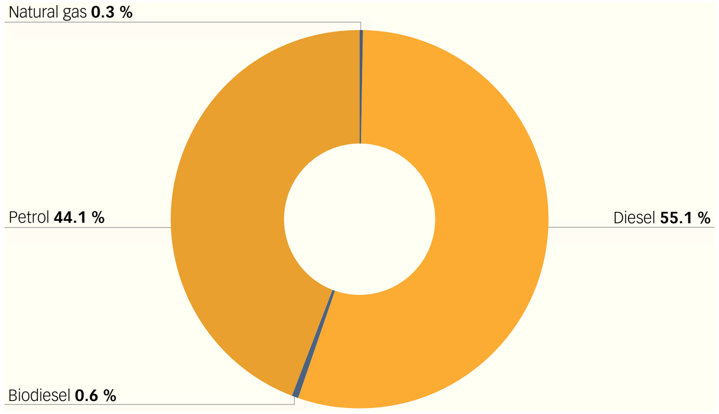


▲ The vehicles which account for the highest percentage of EURO II or previous standards are petrol LDVs, with 44.2%. Buses and coaches account for 34.7%, and petrol passenger cars, 32.1%.

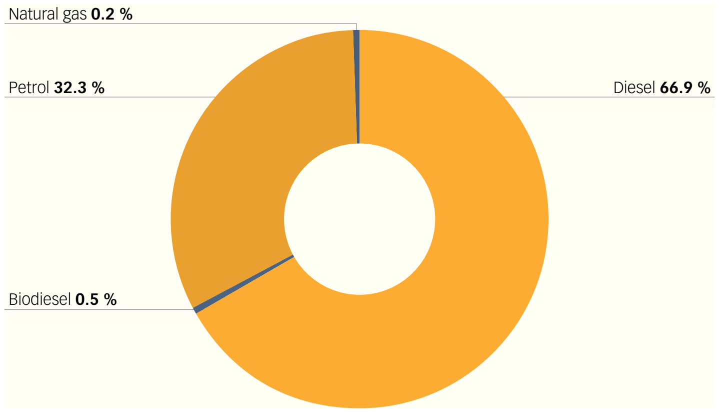
- TYPE OF FUEL USED

In accordance with the characterisation of the vehicle population, the most widely used fuel in 2008 was diesel, with 55.1% of the kilometres covered, while petrol accounts for 44.1%, natural gas 0.3% and biodiesel 0.6%. This distribution is totally different in the ring roads, as the lighter motorcycle traffic and prohibition of mopeds signifies an increase in the proportion of diesel vehicles up to 66.9%.

FIGURE 47 | DISTRIBUTION OF VEHICLES IN CIRCULATION IN BARCELONA CITY AND THE RING ROADS (UPPER) AND ONLY THE LOWER RING ROADS (2008)



▲ Road Traffic: 14.439.16 Mveh-km/year



▲ Road Traffic: 909.54 Mveh-km/year

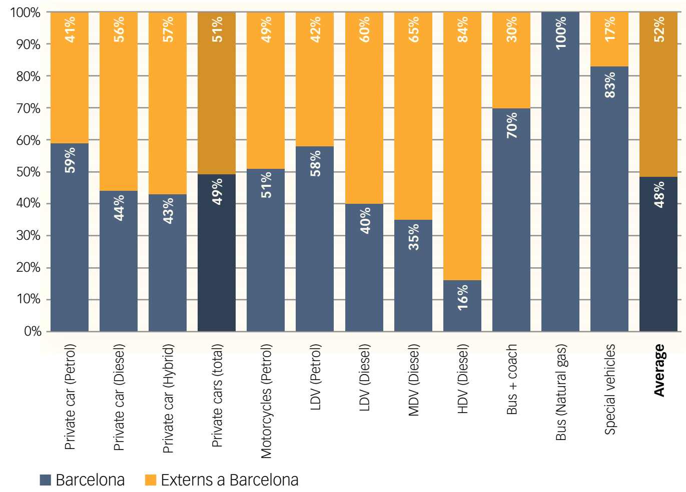
- THE ORIGIN OF THE VEHICLES

The municipality of residence is determined by where the vehicle is registered. It should be noted that the real origin of the vehicle does not have to coincide in all the registries with the municipality where the vehicle resides, although the consistency of the data – and the errors implicit in any sample or database-, lead us to believe that the results are fairly consistent and accurate.

In this respect, the conclusions which can be drawn from the study are as follows:

- 52% of the vehicles in circulation in Barcelona come from other municipalities.
- 49% of the passenger cars in circulation on working days are registered in Barcelona.
- Petrol vehicles have the largest number of owners, with 59%, while diesel vehicles account for 44%. This is understandable if we take into account that the user of diesel vehicles generally drives more kilometres per year, and is therefore driven by users from outside Barcelona.
- As regards LDVs, the proportion is similar to that of passenger cars: 58%, petrol vehicles and 40%, diesel.
- On the other hand, all the medium size or large delivery lorries (over 12 t) are diesel and only 35% and 16% respectively are from Barcelona. This is to be expected in view of the fact that many logistics companies' storage facilities are located in industrial areas outside the city.
- 70% of the diesel buses and coaches (one of the oldest fleets in the city) are registered in Barcelona, while 100% of the natural gas buses are registered there as they form part of the TMB fleet.

FIGURE 48 | CLASSIFICATION OF VEHICLES ACCORDING TO ORIGIN, BY TYPE (2008)



2.2 - Energy consumption

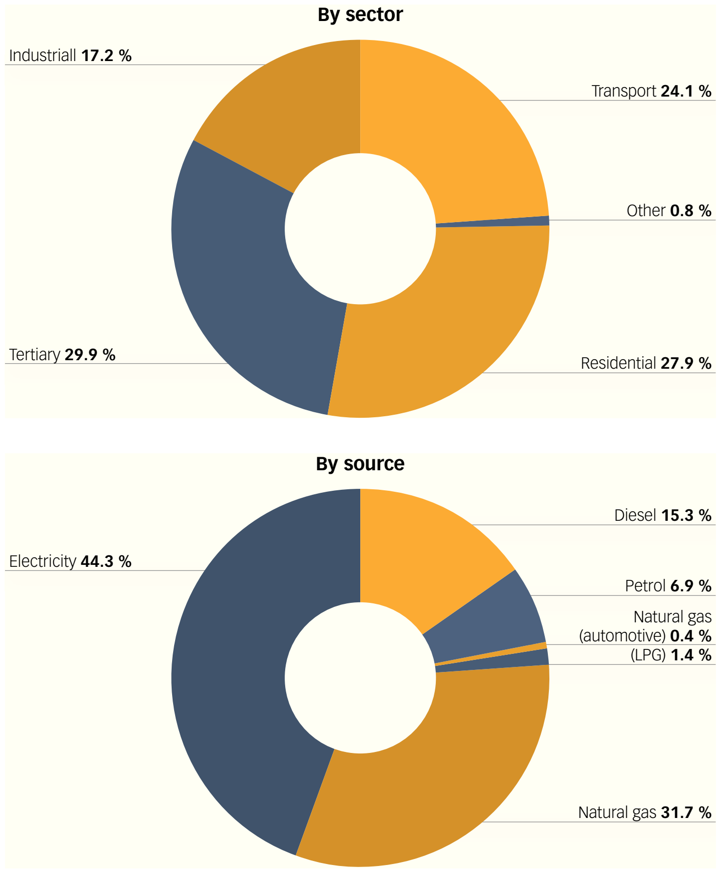
2.2.1 - FINAL ENERGY CONSUMPTION

In 2008, Barcelona consumed 17,001.78 GWh of final energy[13]. This figure can be divided almost equally between the services sector, with 29.9%, the residential sector, with 27.9% and the transport sector with 24.1%. 17.2% of the remainder was consumed by the industrial sector and 0.8%, other sectors (primary, energy, construction and public works).

By energy source, 44.5% of consumption was electricity, 31.8% natural gas, and the remainder diesel (15.4%), petrol (7.0%) and liquefied petroleum gases or LPG (1.4%). Thermal energy generated directly via solar systems was also consumed, although in a very small percentage (almost 0.3%, despite its importance in global energy consumption for hot water) its contribution is not shown in the relevant graph.

This energy consumption represents 1.38% of all the energy consumption of Spain in 2008.

FIGURE 49 | **ENERGY CONSUMPTION IN BARCELONA (2008)**



Source: ICAEN and Repsol

13. This figure includes consumption by the treatment facility of the Estació Depuradora d'Aigües Residuals Metrofang, but not the energy generated using solar thermal systems. If we consider only the treatment proportional to the use made by Barcelona of this water treatment plant, the final energy consumption of Barcelona in 2008 would be 16,896.6 GWh, plus the 52,405 GWh generated that year directly using solar thermal energy.

The consumption ratio per inhabitant was 10.52 MWh/inhab, less than half the energy consumption by inhabitant of Spain (25.47 MWh/inhab in 2008). When comparing these data, it should be borne in mind, however, that the bio-geographic and urban characteristics of Barcelona (a compact, Mediterranean city) signify that the consumption per inhabitant is often lower than in other cities.

Putting energy consumption in Barcelona into perspective, there has been a clear upward trend over recent years, with an average annual growth rate of 0.91% (1999-2008)

TABLE 7 | FINAL ENERGY CONSUMPTION IN BARCELONA (1999/2008)

Final energy consumption in Barcelona (1999/2008)		
	1999 [GWh]	2008 [GWh]
Total	**15.664.78**	**17.001.78**
Total per inhabitant	**10.42 MWh/inhab.**	**10.52 MWh/inhab.**

Putting energy consumption in Barcelona into perspective, there has been a clear upward trend over recent years, with an average annual growth rate of 0.91% (1999-2008) which rose from 15,664.78 GWh of final energy in 1999 to 17,001.78 GWh[14] in 2008 (including consumption of electricity, natural gas, LGP and automotive petrol).

THE SOURCE OF FINAL ENERGY

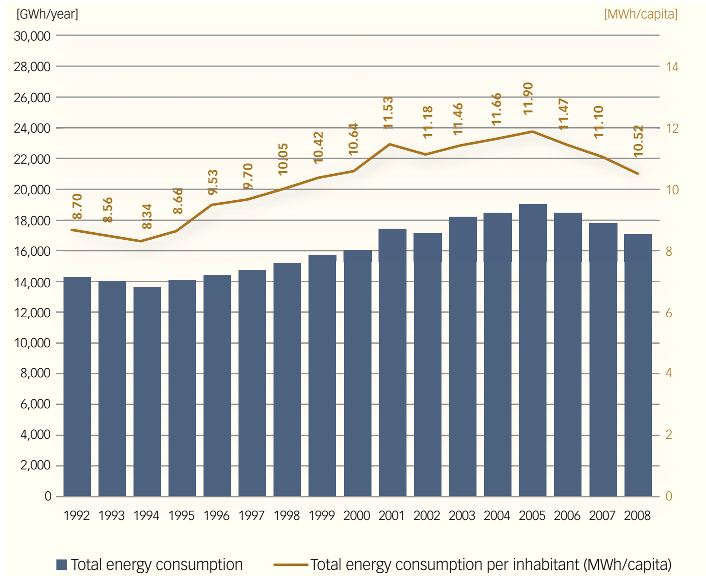
Electricity is a form of final energy as it is produced from other energy sources. When we consider the electric mix of Catalonia in 2008, the electricity consumed in Barcelona originated chiefly from nuclear plants (54.1%) and combined cycle power plants (22.8%). In the case of Spain, the main source was coal, nuclear energy and combined cycles.

The source of the final energy consumed in Barcelona varied significantly during the period 1999-2008. In the case of fuels, while petrol consumption fell 8 points compared to 1999, diesel consumption increased by almost 7 points due to the increase in the population of diesel powered vehicles. Overall, consumption of automotive petrol fell by 23.8% of final energy (1999) to 22.2% (2008), a percentage to which 0.4% of automotive natural gas should be added.

As regards other energy sources, we should highlight the significant increase in the importance of electricity in total consumption (from 37.2% to 44.3%) and the drop in natural gas (from 36.4% to 31.7%) and LGP (from 2.6% to 1.4%).

This increase has not been sustained over time, as until the end of 2005 there were annual growth rates of over 3% and as of that year, consumption has dropped significantly, with rates of -4.03% a year. Consumption per inhabitant increased over the period 1999-2008 at an average annual rate of 0.119% (under 2.24% for the period 1999-2005), up to 10.52 MWh/inhab in 2008.

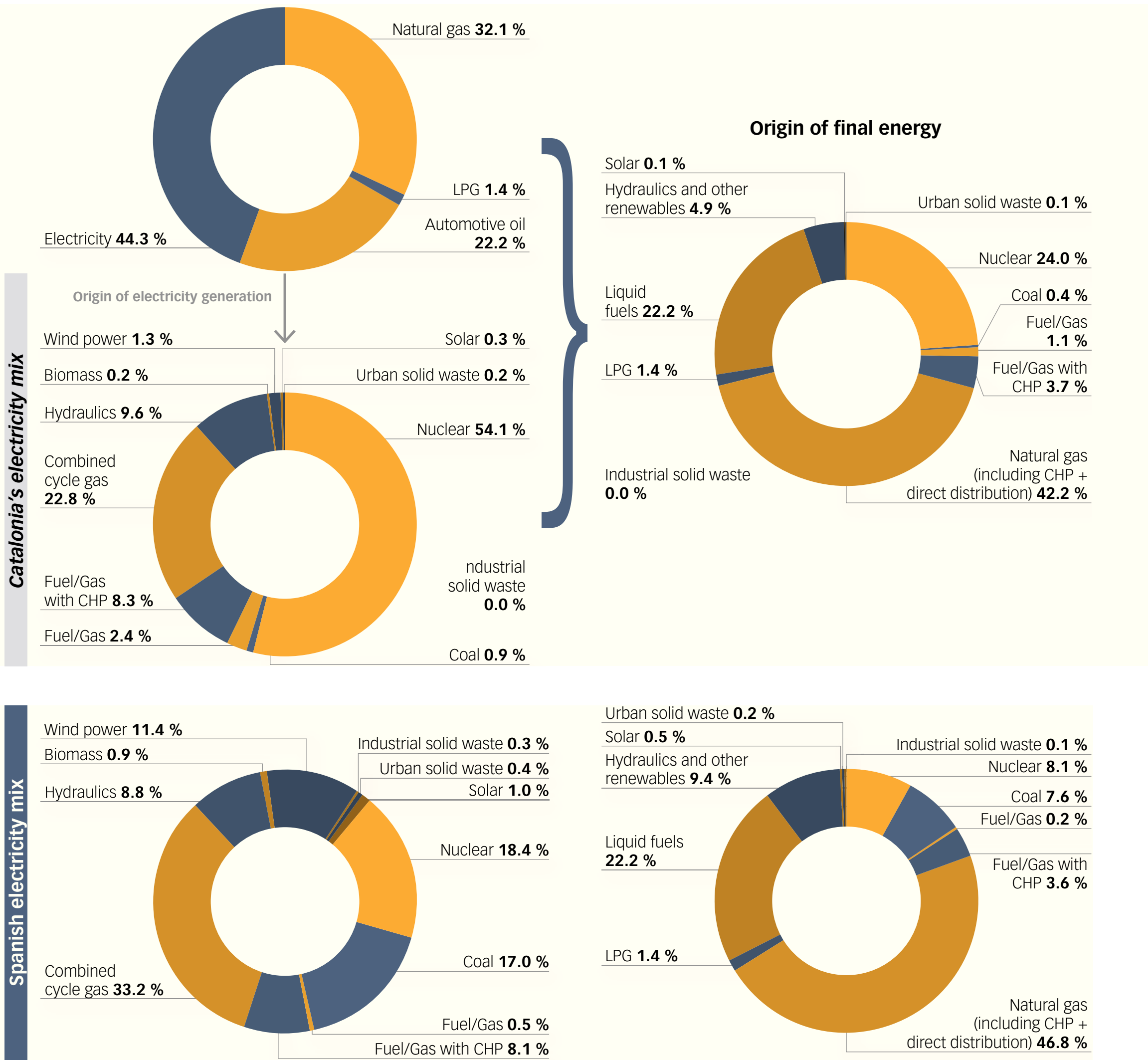
FIGURE 50 | EVOLUTION OF ENERGY CONSUMPTION IN BARCELONA (1992-2008)



Source: ICAEN

14. The recorded value of energy consumption for 1999 was 15,902.9 GWh. However, with the introduction of changes in calculation methodology in 2008, this figure was recalculated to keep it consistent. This modification responds to the difference seen between the registered vehicle fleet and the actual fleet in the streets of Barcelona and this is why the originally-calculated consumption levels of automotive petrol were adapted proportionally to such difference.

FIGURE 51 | SOURCE OF FINAL ENERGY IN SPAIN AND CATALONIA (2008)



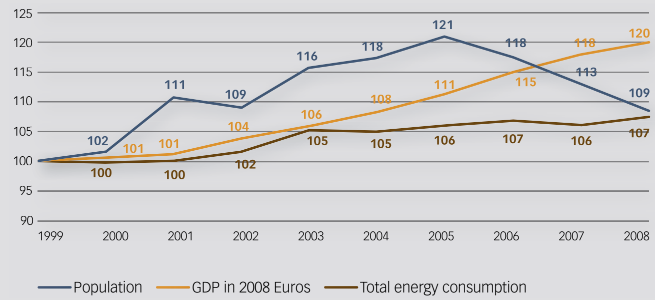
Source: ICAEN

ENERGY AND GROSS DOMESTIC PRODUCT

It has been seen that the increase in energy consumption evolved in a similar manner to the increase in Gross Domestic Product (GDP) until 2005, the year when energy consumption saw a change in trend. The increase in the population, however, does not seem to affect the upward trend in energy consumption. The reasons for this shift in trend in the evolution of energy consumption are to be found in the lower automotive fuel consumption and especially natural gas.

Energy intensity (i.e., the amount of energy per unit of production or service) during the period 1999-2008, therefore fell at an annual rate of -1.11%, to the current level of 269.44 Wh/€. This reduction was chiefly connected with the fact that GDP rose significantly during these years. This a highly positive rate and above the reduction in Spain (-1.01% between 1999-2008, according to the Energy in Spain report by the MITC 2009) and Europe as a whole (-1.03% 1999-2005).

FIGURE 52 | EVOLUTION OF ENERGY AND GDP IN BARCELONA (1999-2008)



2.2.2 - CONSUMPTION BY SECTOR

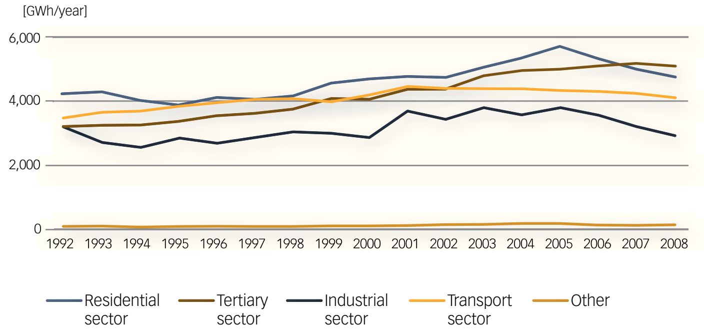
Sectoral trends

The increase in energy consumption in Barcelona between 1999 and 2008 has different causes, by sector. This evolution offers an overview of the change in economic structure undergone by the city over recent years

The increase in energy consumption in Barcelona between 1999 and 2008 has different causes, by sector. This evolution offers an overview of the change in economic structure undergone by the city over recent years,

- The **DOMESTIC SECTOR** saw an energy consumption of 4,749 GWh in 2008, slightly higher than in 1999, which totalled 4,556 GWh. If we analyse the behaviour of the sector during the period 1999-2008, a notable feature is the increase in consumption until 2005 – especially as from 2002, with a growth rate of 3.77%-, and the marked drop during the period 2005-2008 – with a negative rate of 5.85%-, such that during the period 1999-2008 the resulting annual rate was 0.46%. Therefore, between the years 1999 and 2008, consumption in this sector saw virtually no rise.
  To understand this, it must be borne in mind that there was an overall drop in the consumption of natural gas, which the domestic sector is highly sensitive to. The slight increase in the population of Barcelona – which directly affects consumption in this sector -, was accompanied by a change in the density of the residential sector which slightly offset consumption. There was an increase in the intensity of electricity consumption per inhabitant – caused by the growing penetration of technology in homes – and the above drop in the intensity of natural gas consumption per inhabitant.
  The reason for this lower natural gas consumption is, amongst others, the reduction in consumption for heating purposes: in 2006 because it was warmer than 2005, and in 2008 possibly because the onset of the economic crisis gave rise to greater energy saving. Another factor to be taken into account is the reduction in consumption as a result of improved energy efficiency in new dwellings and their equipment.
- In the **SERVICE SECTOR**, energy consumption in 2008 was 5,083 GWh, vs. 4,049 GWh in 1999. The annual growth rate during this period was 2.56%, with a more regular behaviour in the domestic sector, despite the reduction in consumption seen also in 2008.
  This continued increase in service sector consumption during the period 1999-2008 was related to a net growth in the economic activity and greater presence of electrically powered technology. On the other hand, natural gas consumption underwent a slight reduction.
- In the **INDUSTRIAL SECTOR**, consumption in 2008 totalled 2,929 GWh, less than in 1999, 2,993 GWh. The annual growth rate was therefore negative (-0.24%). A year-on-year analysis shows the varied behaviour, with a drop in consumption as from 2005 as occurred in other sectors.
- In the **TRANSPORT SECTOR**, there was a slight rise in consumption during the period 1999-2008, as it rose from 3,965 MWh to 4,100 MWh. However, consumption can be considered virtually stable with an annual growth rate of 0.37%, which over recent years proved negative (-1.69% between 2005 and 2008).
  As a result of governmental policies, there was an increase in the number of users of electric means of public transport (metro, train and tram) and an increase in the natural gas powered fleet of buses. Despite the resulting growth in electricity and natural gas consumption, energy consumption per passenger improved.
  On the other hand, private transport saw a reduction in the number of cars in circulation and an increase in efficiency per km covered, a factor which led to a slight reduction in the consumption of automotive fuel. At the same time, however, the greater traffic of goods lorries, buses and two-wheeled vehicles signified that total petrol consumption in 2008 (diesel and petrol) was practically the same as in 1999.
- The **OTHER SECTORS (OTHERS)** is a group comprising the primary, energy, construction sector and public works. Over all, between the years 1999 and 2008 their energy consumption grew by 3.68%, with a sharp increase until 2005 and a reduction in subsequent years. We should also take into account their limited importance compared to the total energy consumption of the city (0.8%).

FIGURE 53 | EVOLUTION OF ENERGY CONSUMPTION BY SECTOR (1992-2008)



Source: ICAEN and Repsol

TABLE 9 | AVERAGE ANNUAL GROWTH RATES OF ENERGY CONSUMPTION BY SECTOR (1999/2008)

Average annual growth rates of energy consumption by sector (1999/2008)			
	1999 – 2008	1999 - 2005	2005 - 2008
Residential	0.46%	3.77%	-5.85%
Tertiary	2.56%	3.51%	0.68%
Industrial	-0.24%	4.02%	-8.24%
Transport	0.37%	1.42%	-1.69%
Other	3.68%	10.46%	-8.67%
Total	**0.91%**	**3.23%**	**-3.57%**
Total per inhabitant	**0.11%**	**2.24%**	**-4.03%**

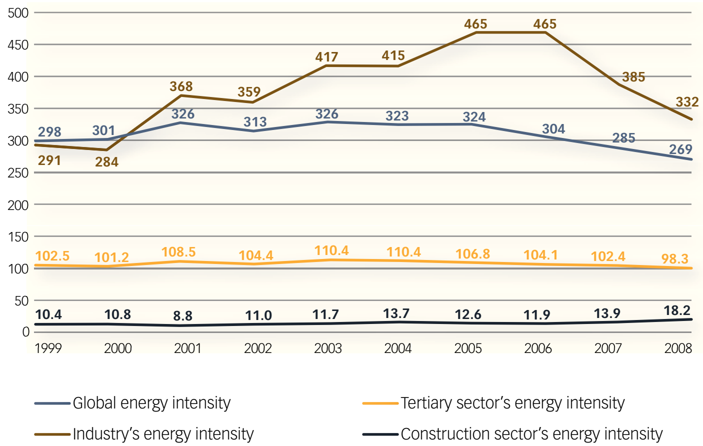
Source: ICAEN and Repsol

TABLE 8 | ENERGY CONSUMPTION BY SECTOR (1999/2008)

Energy consumption by sector (1999/2008)			
	1999	2008	1999 - 2008
Residential	4,556.04	4,749.34	0.46%
Tertiary	4,049.60	5,083.79	2.56%
Industrial	2,993.50	2,929.76	-0.24%
Transport	3,965.88	4,100.83	0.37%
Other	99.76	138.07	3.68%
Total	**15,664.78**	**17,001.78**	**0.91%**
Total per inhabitant	**10.4 MWh/inhab.**	**10,5 MWh/inhab.**	**0.11%**

Source: ICAEN and Repsol

FIGURE 54 | EVOLUTION OF ENERGY INTENSITY BY SECTOR (1999-2008)



▲ The global energy intensity of Barcelona – i.e. the amount of energy used per unit of production or service – has fallen over recent years, from 298 Wh/€ in 1999 to 269 Wh/€ in 2008. This drop was mainly due to the improved efficiency of the industrial sector and, to a lesser extent, the services sector. In the construction sector, however, it has increased.

Traffic study

In order to determine the energy consumption in transport, it is first necessary to estimate the consumption of automotive fuel based on the data and traffic network of the city. This, in turn, enables us to obtain annual vehicles in vehicle-km to calculate the consumption and associated emissions.

In Barcelona, energy consumption for transport (both private vehicles and buses) recorded a significant rise as from 1992, mainly due to the construction of roads offering greater traffic capacity, the Ring-roads. As from 2002, following this period of growth, the city again became saturated and as a result, private cars encountered greater difficulties, a trend resulting in a slight downward curve both in traffic and fuel consumption.

This reduction in traffic was the result not only of the saturation of the road network at peak times, but also of the local government's adoption of measures to make mobility in private vehicles less competitive: The improvement of the bus network, the creation of *"blue zones"* (metered parking), the introduction of the *"green zones"* (residents' parking), the enlargement of spaces for pedestrians...

The renovation of the vehicle population and introduction of better technologies in combustion engines, with the resulting energy efficiency have contributed to the reduction in energy consumption. Thus, if 57% of the vehicles registered in Barcelona in 1999 were older than in 1992 (prior to Euro I), in 2008 this percentage dropped to 18.7%. 32.8% of vehicles were Euro I and II, 22.5% Euro III and 21.8% Euro IV.

We should note that, based on the data obtained in the characterisation study of the vehicle population of Barcelona (see section 2.1.7), the population of passenger cars in circulation is more modern than that of the vehicles registered, a feature which has a major impact on energy consumption and polluting emissions calculations.

FIGURE 55 | EVOLUTION OF THE VEHICLE POPULATION, REGISTERED AND IN CIRCULATION IN BARCELONA (1999-2009)

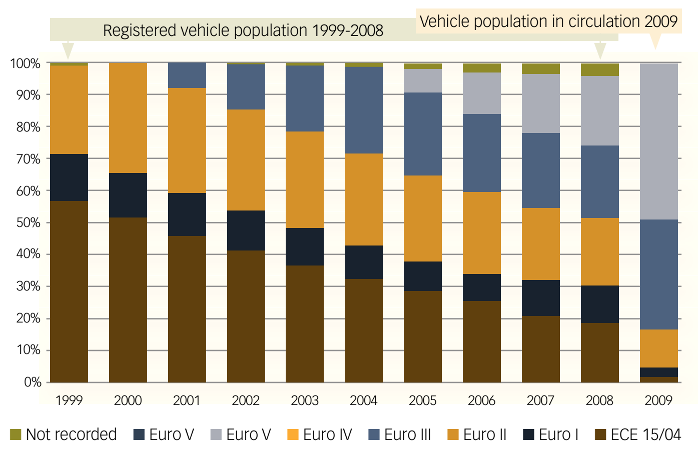
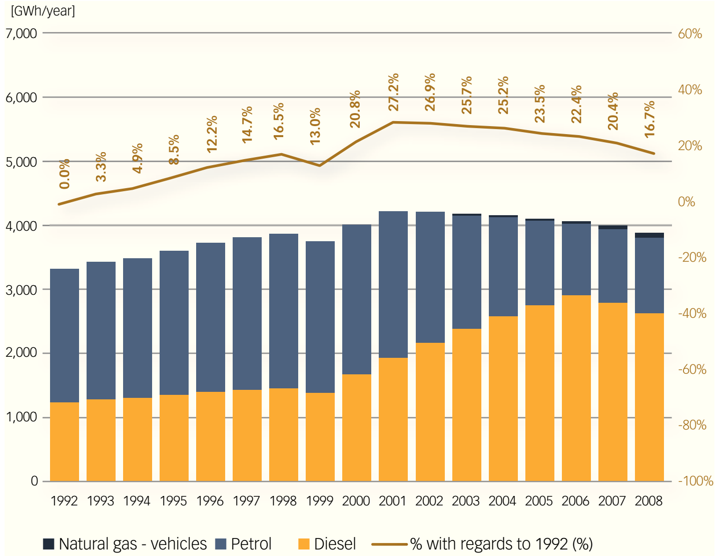
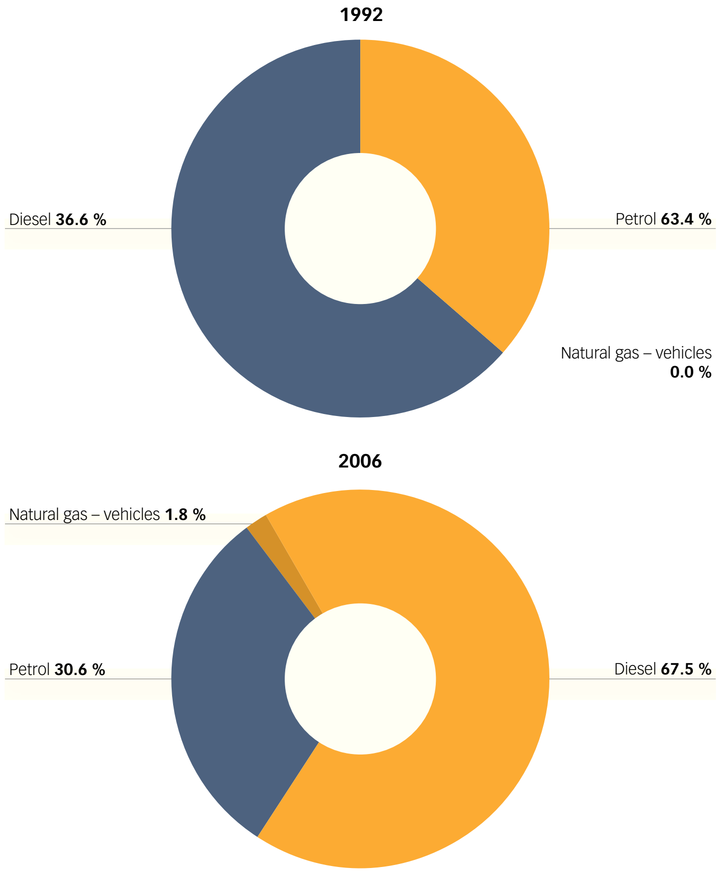


FIGURE 56 | EVOLUTION OF ENERGY CONSUMPTION BY VEHICLES IN BARCELONA (1992-2008)



▲ Based on the difference observed between the registered population and that in circulation, and taking into account that this difference is probably smaller in historic series, the evolution of automotive fuels has been recalculated to standardize the series.

FIGURE 57 | ENERGY CONSUMPTION BY VEHICLES IN BARCELONA (1992-2006)



The annual growth rate of energy consumption by the automotive sector between 1999 and 2008 was 0.37%, although it reached 6.11% during the period 1999-2001. As from that year, until 2008, the rate fell to -1.22%. If we add road traffic consumption with rail consumption (248.47 GWh) and LPG (2.19 GWh), the total consumption by transport in Barcelona stood at 4,100.83 GWh in 2008.

TABLE 10 | ENERGY CONSUMPTION BY VEHICLES IN BARCELONA (1999/2001/2008)

Energy consumption by vehicles in Barcelona			
	1999 [GWh]	2001 [GWh]	2008 [GWh]
Automotive oil (Petrol)	2,361.71	2,290.94	1,178.91
Automotive oil (Diesel)	1,364.22	1,904.05	2,600.07
Automotive natural gas	0.00	0.11	71.19
Electric vehicle (electricity)	0	0	0
Total	**3,725.93**	**4,195.10**	**3,850.17**
Total per inhabitant	**2.48 MWh/ inhab.**	**2.79 MWh/ inhab.**	**2.38 MWh/ inhab.**

TABLE 11 | AVERAGE ANNUAL GROWTH RATES OF ENERGY CONSUMPTION BY VEHICLES IN BARCELONA (1999/2008)

Average annual growth rates of energy consumption by vehicles in Barcelona			
	1999 - 2008	1999 - 2001	2001 – 2008
Automotive	0.37%	6.11%	-1.22%
Energy per inhabitant	-0.44%	6.04%	-2.21%
Population	0.80%	0.06%	1.01%

TABLE 12 | TRANSPORT CONSUMPTION IN BARCELONA (1999/2008)

Transport consumption in Barcelona			
	1999 [GWh]	2001 [GWh]	2008 [GWh]
Total	**3,965.88**	**4,425.90**	**4,100.83**
Total per inhabitant	**2.64 MWh/inhab.**	**2.94 MWh/inhab.**	**2.54 MWh/inhab.**

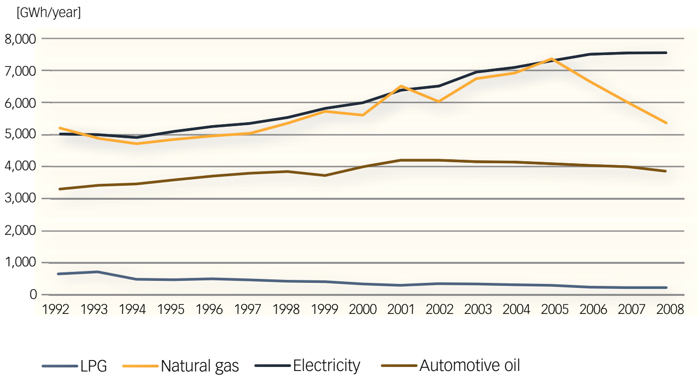
2.2.3 - CONSUMPTION BY ENERGY SOURCE

If we observe the evolution of energy consumption by energy source, the largest energy increase during the period 1999-2008 was led by electricity consumption with an average annual rate of 2.91%, but also the drop in consumption of natural gas and LPG, especially pronounced as from 2005 in the case of natural gas, at figures similar to those of 1992 and below those for 1999.

The reasons for the drop in natural gas consumption is believed to be related to milder weather as from 2006 (2005 was a harsh year, especially in winter, as shown by the generalised peak in energy consumption in Catalonia and in Spain).

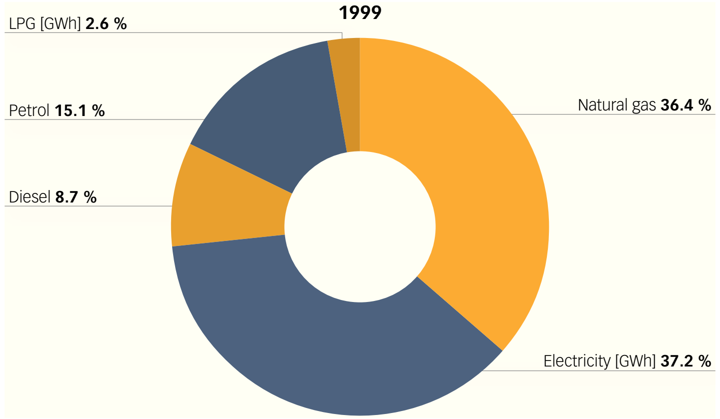
We also observe a reduction in the increase in consumption of automotive fuels, petrol and diesel which is attributed to two factors: less private transport road traffic in the city and enhanced energy efficiency of the vehicle population in circulation, as explained above.

FIGURE 58 | EVOLUTION OF ENERGY CONSUMPTION IN BARCELONA BY ENERGY SOURCE (1992-2008)

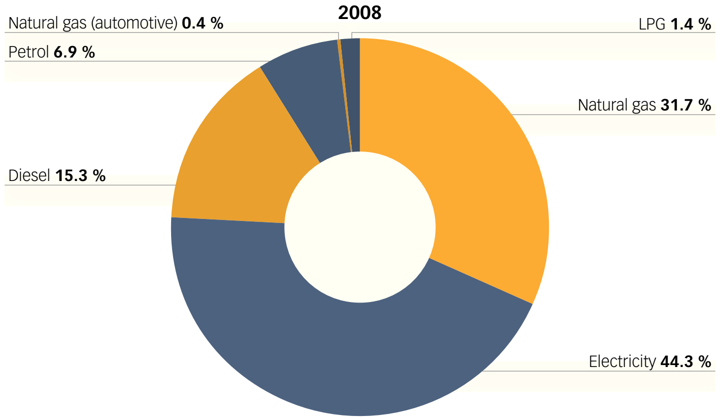


Source: ICAEN (electricity, natural gas and LPG) and Barcelona Regional (automotive fuel)

FIGURE 59 | ENERGY CONSUMPTION IN BARCELONA BY ENERGY SOURCE (1999/2008)



▲ Consumption in 2008: 15,664.78 GWh



▲ Consumption in 2008: 17,001.78 GWh

Source: ICAEN

TABLE 13 | AVERAGE ANNUAL GROWTH RATES OF ENERGY CONSUMPTION IN BARCELONA BY ENERGY SOURCE (1999/2008)

Average annual growth rates of energy consumption in Barcelona by energy source		
	1999 - 2005	1999 - 2008
Electricity	3.80%	2.91%
Natural gas	4.22%	-0.64%
LPG	-5.32%	-6.21%
Automotive oil	1.49%	0.37%
Total	**3.23%**	**0.91%**
Total per inhabitant	**2.24%**	**0.11%**

TABLE 14 | FINAL ENERGY CONSUMPTION IN BARCELONA, BY ENERGY SOURCE (1999/2008)

Final energy consumption in Barcelona, by energy source		
	1999 [GWh]	2008 [GWh]
Electricity	5,824.20	7,536.66
Natural gas	5,699.67	5,381.83
LPG	414.98	233.12
Automotive oil	3,725.93	3,850.17
Total	**15,664.78**	**17,001.8**
Total per inhabitant	**10.42 MWh/inhab.**	**10.52 MWh/inhab.**

Source: ICAEN (electricity, natural gas), REPSOL-YPF (LPG) and Barcelona Regional (automotive fuel)

Evolution of electricity consumption

Barcelona consumed 7,536.66 GWh of electricity in 2008, 29% up over 1999. By sectors, consumption was distributed as follows: 55.1% in the services sector, 30.4% in the residential sector, 9.4% in industry and 5.1% other minority sectors. When comparing the distribution of electricity consumption in 2008 with that of 1999, we observe that, over this period, the services sector increased by 4.2%, while the industrial sector fell by 5.1%.

TABLE 15 | ELECTRICITY CONSUMPTION IN BARCELONA, BY SECTOR (1999/2008)

Electricity consumption in Barcelona, by sector		
	1999 [GWh]	2008 [GWh]
Residential (electric)	1,711.36	2,289.58
Tertiary (electric)	2,961.77	4,148.98
Industrial (electric)	845.49	711.57
Traction (electric)	205.83	248.47
Other (electric)	99.75	138.06
Total	**5,824.20**	**7,536.66**
Total per inhabitant	**3.87 MWh/inhab.**	**4.66 MWh/inhab.**

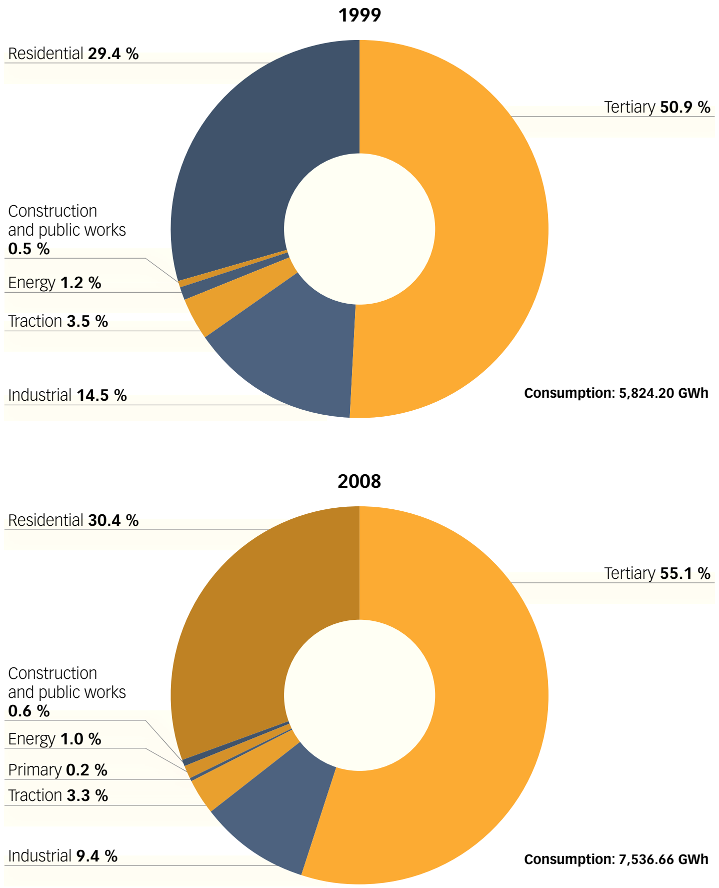
Source: ICAEN

TABLE 16 | AVERAGE ANNUAL GROWTH RATES OF ELECTRICITY CONSUMPTION (1999-2008)

Average annual growth rates of electricity consumption	
	1999 - 2008
Electricity	2.91%
Electricity per inhabitant	2.08%
Population	0.80%

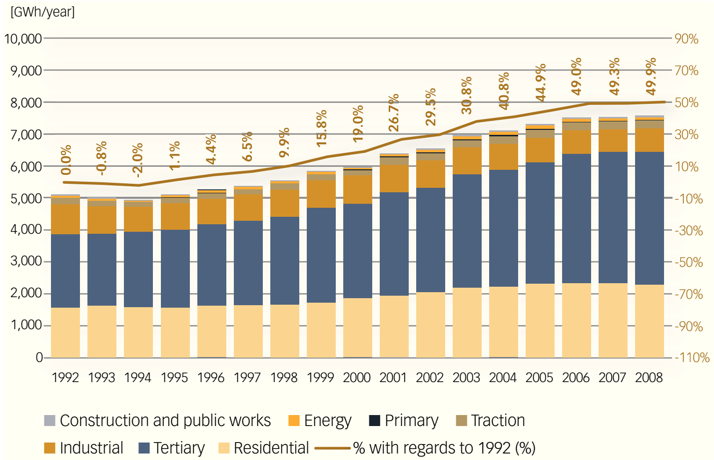
Source: ICAEN

FIGURE 60 | ELECTRICITY CONSUMPTION IN BARCELONA, BY SECTOR (1999/2008)



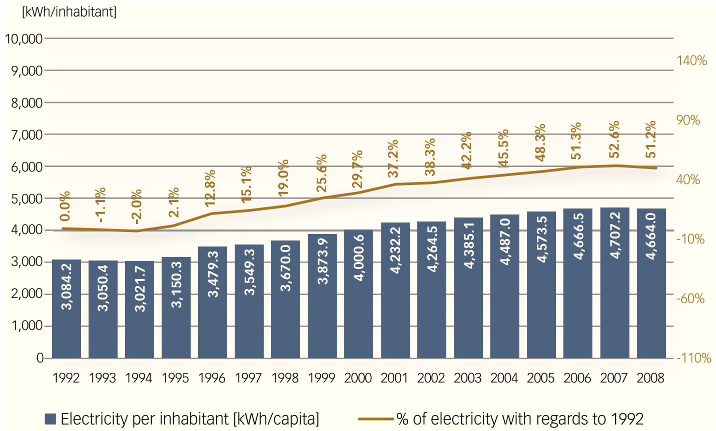
Source: ICAEN

FIGURE 61 | EVOLUTION OF ELECTRICITY CONSUMPTION (1992-2008)



Source: ICAEN

FIGURE 62 | EVOLUTION OF ELECTRICITY CONSUMPTION PER INHABITANT (1992-2008)



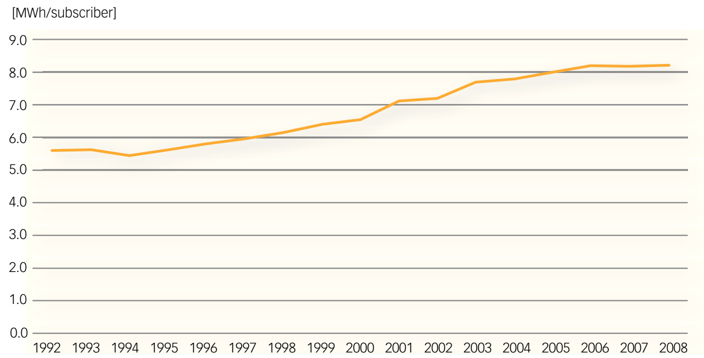
The evolution of electricity consumption has always shown an upward trend (except in 93 and 94), and in particular in 1996 and 2003. As from 2006 the increase in consumption slowed down compared to previous years.

The ratio of electricity consumption per inhabitant underwent a similar process, as the increase as from 2006 was well below that of earlier years, totalling 4.65 MWh/inhab in 2008. However, if we consider only the residential sector, consumption per inhabitant reached 1.42 MWh/inhab in 2008, while in 1999 this figure was 1.14 MWh/inhab.

The historic evolution of the electricity consumption ratio by service connection also rose at a rate of 1.94% a year during the period 1992-1999 and 2.81% a year during the period 1999-2008. The largest growth took place between 1999-2003, with an annual rate of 4.70%.

In general, the entire 1999-2008 period was heavily influenced by the technological evolution of society, both in the use of new appliances and the increase in the number of infrastructures necessary to meet the needs of the population.

FIGURE 63 | EVOLUTION OF ELECTRICITY CONSUMPTION BY SUBSCRIBER (1992-2008)



Source: ICAEN

n this respect, the residential sector is that which has seen most growth in technological equipment, especially with the generalised installation of air-conditioning systems and the Internet boom, which explains why consumption by this sector is greater than the increase in the rest, both in absolute terms and as a ratio per inhabitant.

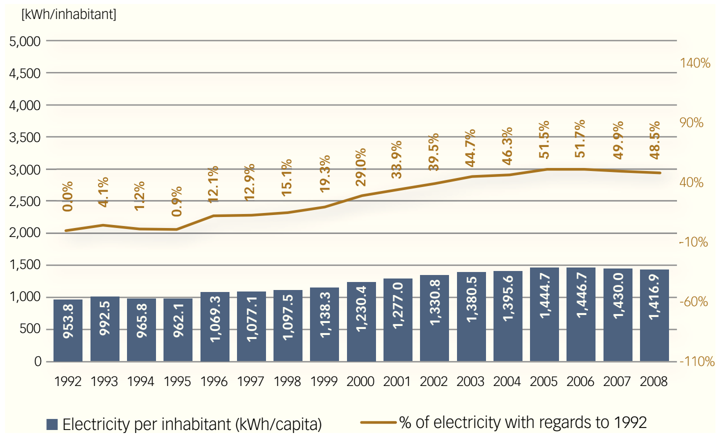
Despite this increase, during the latter years of the period 1999-2008, electricity consumption in the residential sector levelled out and even fell slightly during the last two years. The commencement of the economic crisis and purchase of more efficiency equipment would seem to be the causes which have led to this energy saving, according to a technical study carried out by Repsol[15], in which it estimated that the specific consumption of equipment had fallen by over 20%.

TABLE 17 | AVERAGE ANNUAL GROWTH RATES OF ELECTRICITY CONSUMPTION IN THE RESIDENTIAL SECTOR IN BARCELONA (1999-2008)

Average annual growth rates of electricity consumption in the residential sector in Barcelona	
	1999 - 2008
Residential electricity	3.29%
Residential electricity per inhabitant	2.46%
Population	0.80%

Source: ICAEN

FIGURE 64 | EVOLUTION OF ELECTRICITY CONSUMPTION OF THE RESIDENTIAL SECTOR PER INHABITANT (1992-2008)

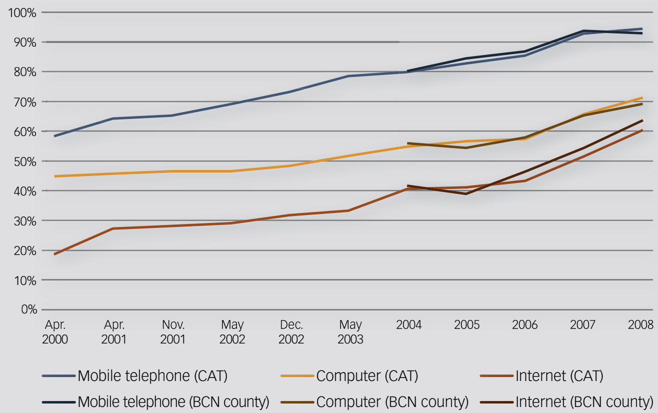


15. Repsol Technical Study Consumo de energía en España 2008.

HOME EQUIPMENT AND ENERGY CONSUMPTION

Over recent years there have been significant changes in the appliances in Spanish homes, as some have been renewed (refrigerators, freezers, washing machines and dishwashers, especially) and new ones have been added, in particular those related to communication technologies. Two examples of this are the increase in the number of computers (+11% between 2004 and 2007) and microwave ovens (+24% during the period 2000-2005). The improved efficiency of these appliances is evident from the reduction in specific consumption, approximately -23% to -37% during the period 1990 to 2006, according to different studies.

FIGURE 65 | EVOLUTION OF ICT EQUIPMENT IN HOMES IN CATALONIA (2000-2008)



Source: Observatory for the Information Society [OBSI] and IDESCAT

Evolution of natural gas consumption

The consumption of natural gas in Barcelona in 2008 was 5,381.83 GWh. By sector, 41.9% was consumed in the residential sector, 40.7% in the industrial sector and 17.4% in the services sector. These percentages are very similar to those of 1999.

Natural gas consumption underwent a sharp increase during the period 1999-2005, although as from that year, consumption dropped markedly until 2008, with figures similar to those of 1992 and lower than in 1999.

An analysis by sector shows that while the average annual increase in the residential and services sector in the period 1999-2005 was 3.87% and 1.49% respectively, during the period 2005-2008 there were annual reductions of 10.11% and 7.70% respectively. The industrial sector also saw similar fluctuations, because while consumption increased at a rate of 5.85% in the period 1999-2005, subsequently this trend reversed during the period 2005-2008 at a rate of 10.04%. The industrial sector is the only one which has a virtually identical consumption between the years 1999 and 2008.

As regards the consumption of natural gas per inhabitant, this figure stood at 3.79 MWh in 1999, then increasing by 3.22% a year to a total of 4.58 MWh/inhabitant in 2005. One of the reasons behind this peak in consumption would be the low winter temperatures recorded that year which, compared with those of other years, showed differences in the minimum temperatures of over one degree.

TABLE 18 | CONSUMPTION OF NATURAL GAS IN BARCELONA, BY SECTOR (1999/2005/2008)

Consumption of natural gas in Barcelona, by sector			
	1999 [GWh]	2005 [GWh]	2008 [GWh]
Residential (natural gas)	2,472.22	3,105.53	2,255.90
Tertiary (natural gas)	1,087.83	1,188.66	934.81
Industrial (natural gas)	2,139.62	3,009.77	2,191.12
Total	**5,699.67**	**7,303.96**	**5,381.83**
Total per inhabitant	**3.79 MWh/ inhab.**	**4.58 MWh/ inhab.**	**3.33 MWh/ inhab.**

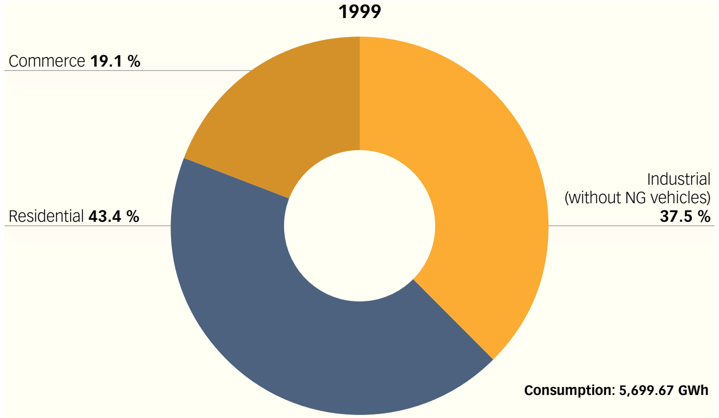
Source: ICAEN

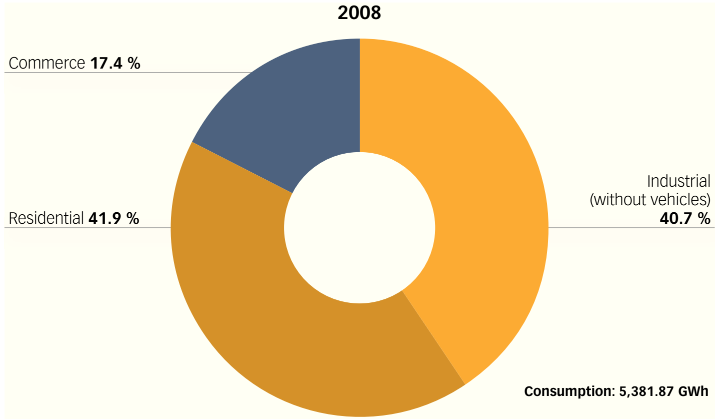
TABLE 19 | AVERAGE ANNUAL GROWTH RATES OF NATURAL GAS CONSUMPTION (1999-2008)

Average annual growth rates of natural gas consumption		
	1999 - 2005	1999 - 2008
Natural gas	3.84%	-0.64%
Natural gas per inhabitant	3.22%	-6.96%
Population	0.97%	0.80%

Source: ICAEN

FIGURE 66 | CONSUMPTION OF NATURAL GAS IN BARCELONA, BY SECTOR (1999/2008)



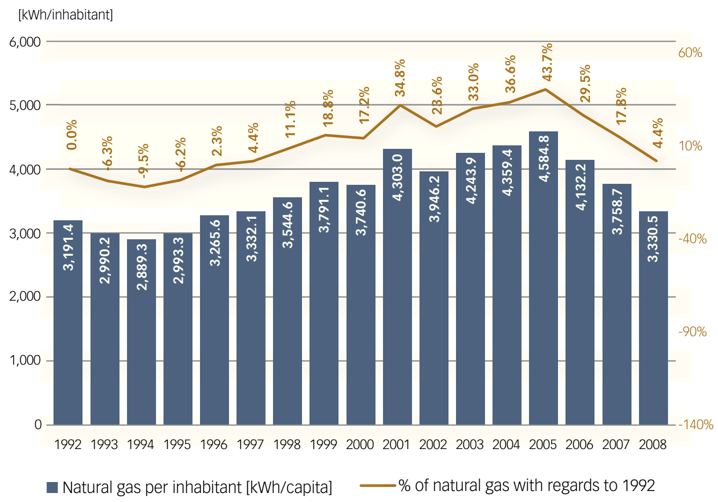


Source: ICAEN

As from 2005 there was a clear change in the trend and the ratio fell at an annual rate of 10.11% to 3.33 MWh/inhabitant in 2008. Such a low per capita consumption had not been seen since the year 1997.

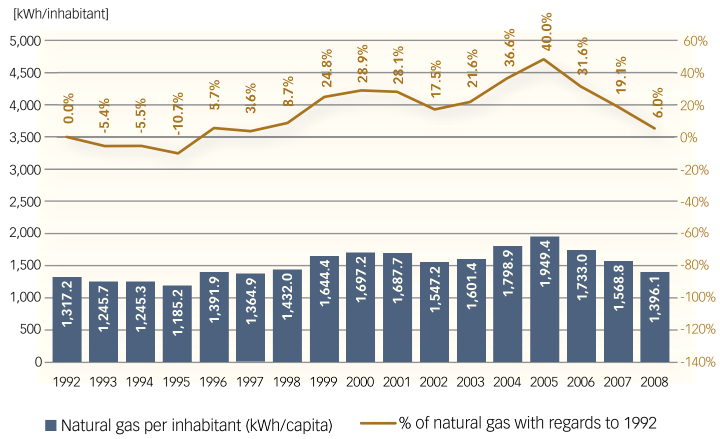
Despite this, the energy efficiency improvement policies in housing and heating systems may also be a factor – though to a lesser degree - together with possible changes in the facilities in refurbished homes (installation of electrical systems in housing intended for rent, with a lower investment). This contrasts with the evolution of electricity consumption in the residential sector, opposed to that of natural gas. If we analyse solely the residential sector, we can see how the reduction in natural gas consumption is greater than that of consumption throughout the city for the period 2005-2008.

FIGURE 67 | EVOLUTION OF NATURAL GAS CONSUMPTION PER INHABITANT (1992-2008)



Source: ICAEN

FIGURE 68 | EVOLUTION OF NATURAL GAS CONSUMPTION IN THE RESIDENTIAL SECTOR PER INHABITANT (1992-2008)



Source: ICAEN

TABLE 20 | AVERAGE ANNUAL GROWTH RATES OF NATURAL GAS CONSUMPTION IN THE RESIDENTIAL SECTOR (1999-2008)

Average annual growth rates of natural gas consumption in the residential sector		
	1999 - 2005	2005 - 2008
Residential natural gas	3.87%	-1.01%
Residential natural gas per inhabitant	2.88%	-1.8%
Population	0.97%	0.80%

Source: ICAEN and Barcelona City Council

Evolution of the consumption of liquefied petroleum gases (LPG)

The consumption of liquefied petroleum gases or LPG (butane, propane and mixes) in Barcelona was 233.12 GWh in 2008, well below the 414.98 GWh of 1999. Therefore, the downward trend is inversely proportional to the upward trend in consumption of natural gas and electricity.

TABLE 21 | CONSUMPTION OF LIQUEFIED PETROLEUM GASES IN BARCELONA BY SECTOR (1999/2008)

Consumption of liquefied petroleum gases in Barcelona by sector		
	1999 [GWh]	2008 [GWh]
Residential (butane)	372.46	203.86
Commerce/industrial (propane)	8.39	27.07
Traction (mix)	34.13	2.19
Total	**414.98**	**233.12**
Total per inhabitant	**0.28 MWh/inhab.**	**0.14 MWh/inhab.**

Source: ICAEN

TABLE 22 | AVERAGE ANNUAL GROWTH RATES OF LIQUEFIED PETROLEUM GAS CONSUMPTION (1999-2008)

Average annual growth rates of liquefied petroleum gas consumption	
	1999 - 2008
LPG	-6.21%
LPG per inhabitant	-6.96%
Population	0.80%

Source: Repsol-YPF

Since 2005 (the year in which practically 95% of the LPG sold in Barcelona was butane, closely related to the residential sector) there was an increase in the proportion of propane for the services sector to a total of 11.6% in 2008. Global consumption of LPG and especially butane in the residential sector continued to fall as from 1999, except for a recovery in 2002. Butane mix (used in certain machinery used in logistics) has almost disappeared. Thus, current sales of LPG in Barcelona are mostly of butane and there is a small proportion of propane which is used in the commercial/industrial sector.

As regards the consumption of LPG per inhabitant, in 2008 this was 0.14 MWh with a rate of reduction of 6.96% during the period 1999-2008.

FIGURE 69 | EVOLUTION OF THE CONSUMPTION OF LIQUEFIED PETROLEUM GASES (1992-2008)

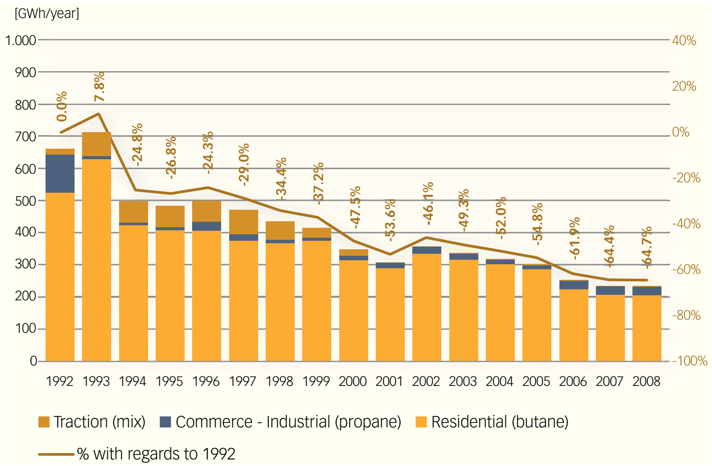
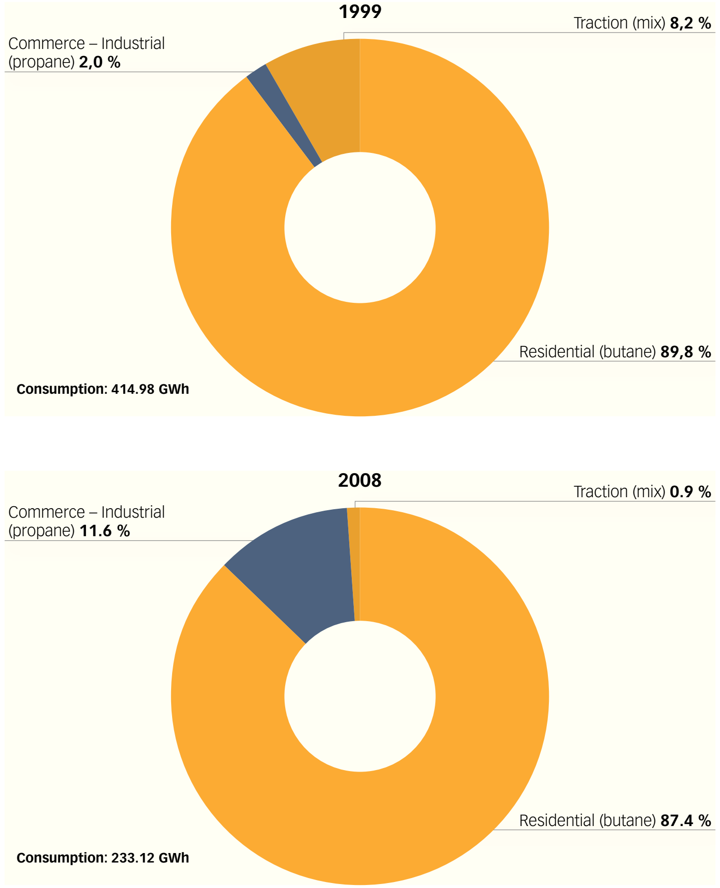


FIGURE 70 | CONSUMPTION OF LIQUEFIED PETROLEUM GASES IN BARCELONA BY SECTOR (1999/2008)



Source: Repsol-YPF

FIGURE 71 | EVOLUTION OF THE CONSUMPTION OF LIQUEFIED PETROLEUM GASES PER INHABITANT (1992-2008)

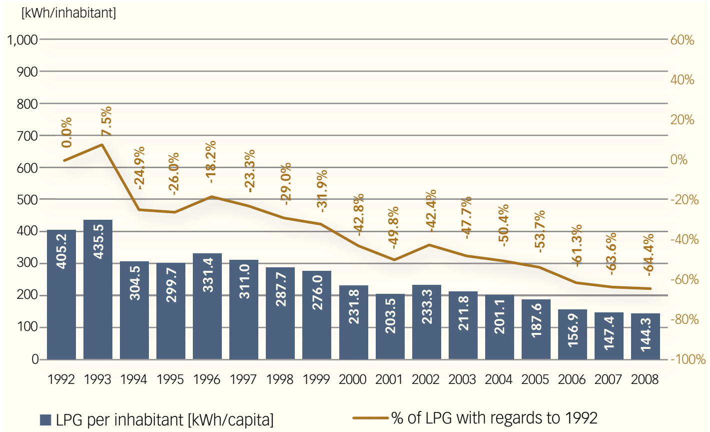
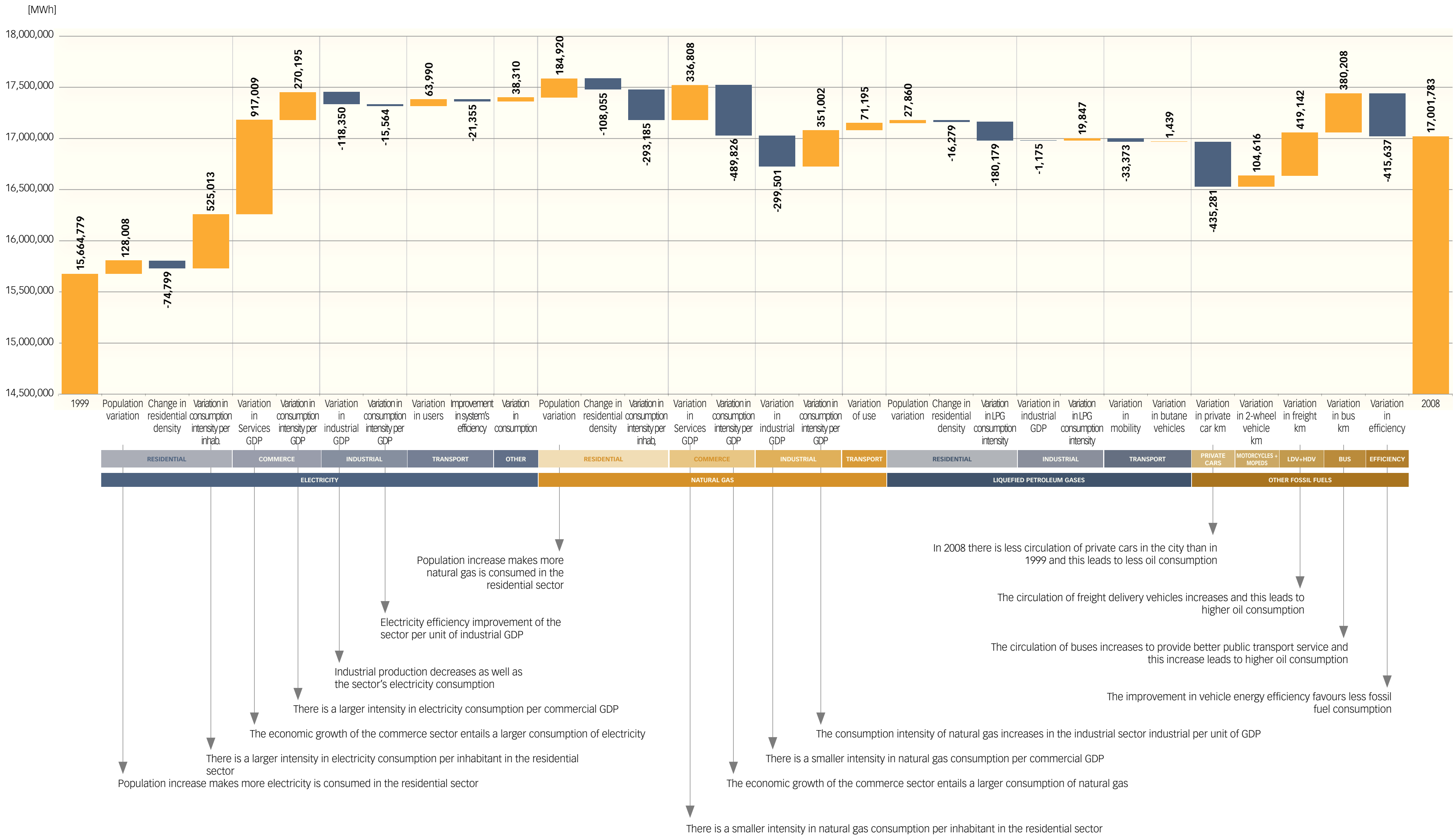


FIGURE 72 | VARIATION IN THE CONSUMPTION OF FINAL ENERGY IN BARCELONA (1999-2008)

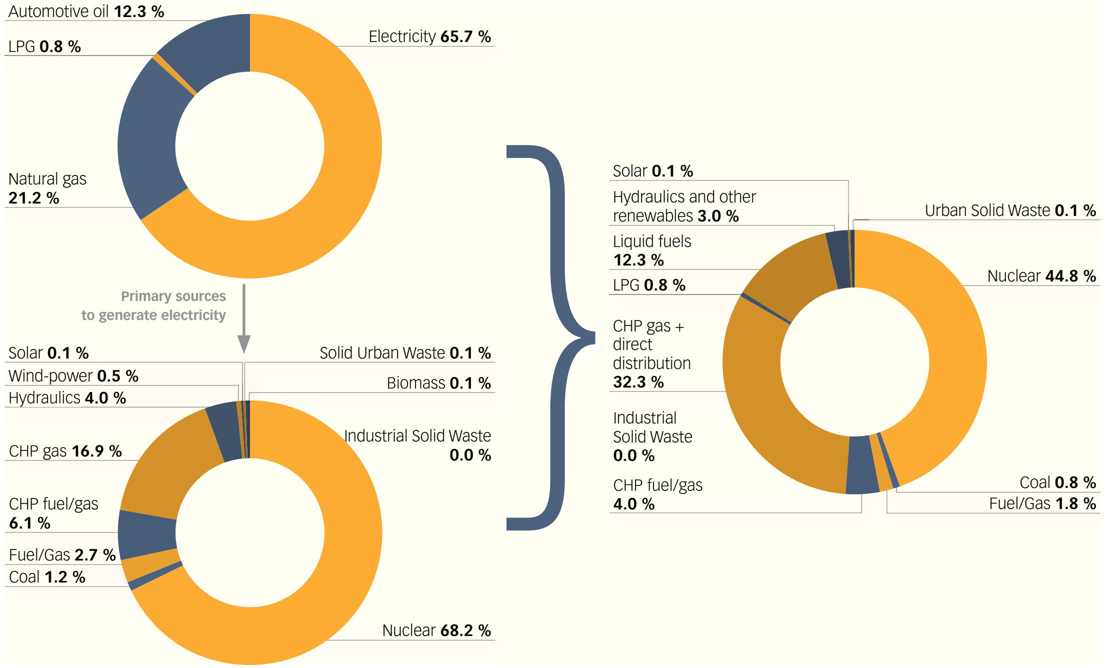


2.2.4 - PRIMARY ENERGY CONSUMPTION

In order to meet the final energy demand of Barcelona in 2008 (17,001.78 GWh of final energy), 30,783.60 GWh of primary energy were necessary, 9.3% more than in 1999. This figure includes the transformation losses of primary energy into final energy in the electricity production system of Catalonia, and the consumption of the energy sector itself and an estimate of the losses in energy transmission.

Notwithstanding this, the efficiency of the energy system is practically the same as in 1999, despite an improvement in the electricity system, probably due to the greater importance of combined cycles in thermal plants (which are more efficient than conventional systems), and renewable energy sources.

FIGURE 73 | PRIMARY ENERGY SOURCES IN BARCELONA (2008



Of the total primary energy, 65.7% was used to generate and transmit electricity, while the rest is distributed between natural gas (21.2%), liquid fuels for transport (12.3%) and LPG (0.8%).

Of the primary energy necessary to produce electricity, 68.2% was generated by nuclear energy (in 1999 this percentage was 77.9%), while 16.9% was generated by natural gas used in the new combined cycles (in 1999 it was 0% as combined cycle technology did not exist).

The arrival of combined cycles for electricity generation in Catalonia has reduced the percentage generated by nuclear energy by 9.7 points; generation by conventional thermal plants using fuel/gas by 4.4 points, while coal powered plants account for practically the same proportion as in 1999.

TABLE 23 | PRIMARY AND FINAL ENERGY CONSUMPTION IN BARCELONA (1999/2008)

Primary and final energy consumption in Barcelona		
	1999	2008
Final energy consumption	15,664.78 GWh	17,001.78 GWh
Primary energy consumption	28,158.87 GWh	30,783.60 GWh
System's efficiency	55.63%	55.23%
System's electricity efficiency	33.6%	37.3%

Source: ICAEN

2.3 - Energy generation

2.3.1 - GLOBAL GENERATION

In 2008, the energy infrastructures located in the municipality of Barcelona and Besòs (boundary with Barcelona), produced 5,243.2 GWh of electrical energy (5,684 GWh in 2006) and 52.4 GWh of solar thermal energy.

Of this energy, 93% was generated at the major production plants (Besòs 3 + 4, and Sant Adrià 1 + 3), which form part of the ordinary regime (OR). The remaining 7% was produced at small energy plants using cogeneration, at renewable energy facilities and waste energy recovery plants. All these facilities form part of the Special Regime (SR).

FIGURE 74 | ENERGY PRODUCTION FACILITIES IN BARCELONA

Ordinary regime facilities

- Thermal power plant (Sant Adrià)
- CHP plant (Besòs)

Special regime facilities

- Cogeneration engines
- Renewable sources
- Waste valorisation

FIGURE 75 | ENERGY PRODUCTION FACILITIES IN BARCELONA

PRODUCTION UNDER THE ORDINARY REGIME AND SPECIAL REGIME

Under the Spanish law on the electricity sector (54/1997), electricity production can take two forms, depending on the technology and the primary energy resource used:

- Ordinary regime: This is produced using conventional technologies utilised in coal, fuel-oil, natural gas, combined-cycle, nuclear plants, etc.
- Special regime: This refers to production in plants with an output no greater than 50 MW which use renewable sources as their primary energy (biomass, hydraulic, solar and wind) or waste, together with others such as cogeneration, which offer a high level of energy efficiency and saving..

2.3.2 - THE ORDINARY AND SPECIAL REGIMES

Production under the ordinary regime

In the Besòs area, adjacent to Barcelona, there are several electricity production facilities which meet a large part of the energy demand of Barcelona and its surrounding area: the Sant Adrià Plant, with three conventional thermal units (one of them closed down in January 2008) and the combined-cycle plants of Besòs 3 and Besòs 4. Prior to this, the Besòs 1 and 2 and Badalona II were closed down.

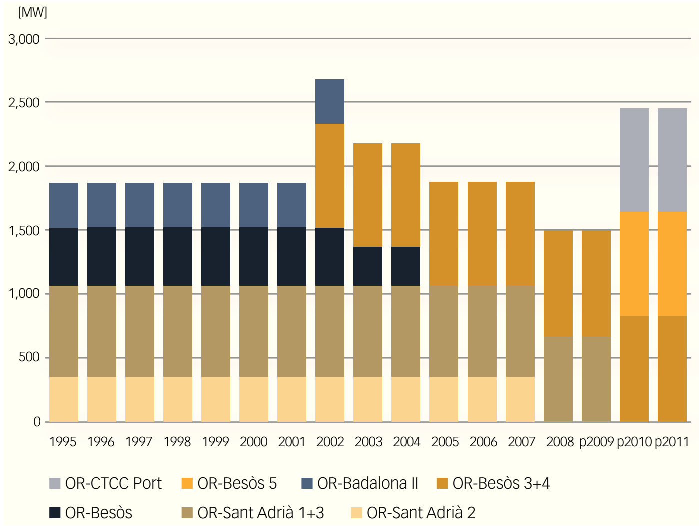
In 2008, in the Besòs area, and considering solely the ordinary regime (OR), there were 1,478 MW of installed capacity distributed as follows: 55.4% combined-cycles (Besòs 3 and 4) 44.6% thermal fuel/gas plants (Sant Adrià 1 and 3). The fuel plant (Sant Adrià 2) was closed down by the Generalitat de Catalunya in January 2008 due to its emissions, as this fossil fuel produces much more pollution than the natural gas which powers the Sant Adrià 1 and 3 facilities. This output produced 4,907 GWh in 2008, 96.3% by means of combined-cycles (Besòs 3 and 4) and the remaining percentage by means of conventional thermal plants (Sant Adrià 1 and 3).

The evolution of the percentage of energy produced in Besòs compared to that generated by Catalonia (only ordinary regime) as a whole, shows how this territory has gained in importance over recent years, as the new combined-cycle plants in Besòs have produced much more energy than the former plants

The evolution of the percentage of energy produced in Besòs compared to that generated by Catalonia (only ordinary regime) as a whole, shows how this territory has gained in importance over recent years, as the new combined-cycle plants in Besòs have produced much more energy than the former plants. Thus, in 2008, 13% of the total energy was produced in Besòs (Sant Adrià 1+3 and Besòs 3+4), while in 2001, the year before the Besòs 3+4 combined-cycle plants were commissioned, this figure was just 4.7%.

The installed capacity in 2008 under the ordinary regime in Besòs, compared to the total installed capacity in Catalonia was lower than in 2001 (16.1%, vs. 23.4%)

FIGURE 76 | EVOLUTION OF THE INSTALLED ELECTRICITY CAPACITY AND FORECAST FOR THE FUTURE (ORDINARY REGIME)



Source: Red Eléctrica de España

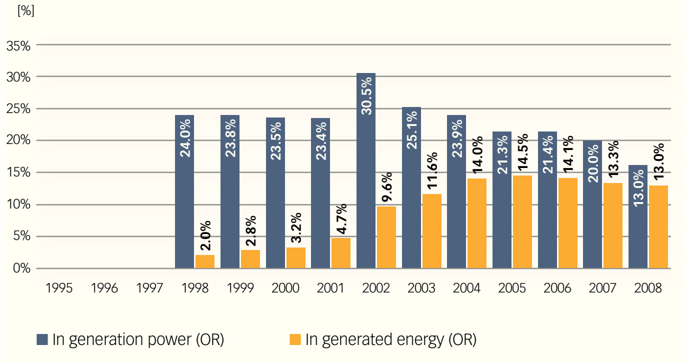
▲ In 2002 there was a peak of installed capacity due to the temporary overlapping of outputs during the substitution of the classic thermal plants by combined-cycles.

TABLE 24 | EVOLUTION OF THE INSTALLED ELECTRICITY CAPACITY IN FACILITIES AND TOTAL PRODUCTION 1995-2008 (ORDINARY REGIME)

Ordinary regime [MW]	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
OR-Sant Adrià 2 [Fuel]	350	350	350	350	350	350	350	350	350	350	350	350	350	0
OR-Sant Adrià 1+3 [Fuel/Gas]	700	700	700	700	700	700	700	700	700	700	700	700	700	659
OR-Besòs [Fuel/Gas]	450	450	450	450	450	450	450	450	300	300	0	----	----	----
OR-Besòs 3 and 4 [CHP]	0	0	0	0	0	0	0	800	800	800	800	812	812	819
OR-Badalona II [Fuel]	344	344	344	344	344	344	344	344	0	----	----	----	----	----
OR-Besòs 5 [CHP]	----	----	----	----	----	----	----	----	----	----	----	----	----	----
OR-CTCC Port of Barcelona	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Ordinary regime power [BESÒS ENVIRONMENT]	**1,844**	**1,844**	**1,844**	**1,844**	**1,844**	**1,844**	**1,844**	**2,644**	**2,150**	**2,150**	**1,850**	**1,862**	**1,862**	**1,478**

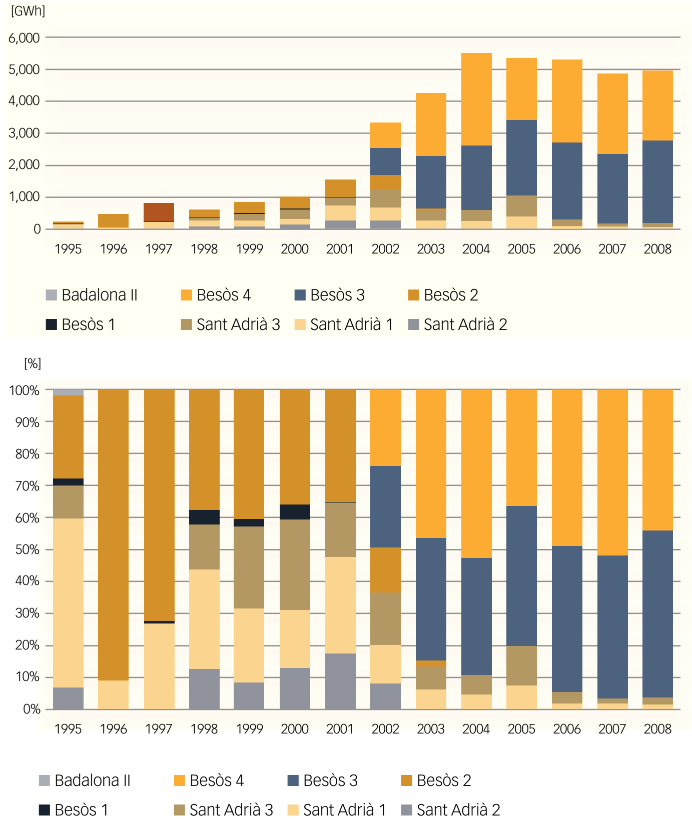
Ordinary regime [GWh]	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
OR-Sant Adrià 2 [Fuel]	15	0	0	75	68	128	264	264	0	-----	-----	-----	-----	-----
OR-Sant Adrià 1+3 [Fuel/Gas]	141	39	211	268	401	463	719	939	562	579	1,040	279	161	179
OR-Besòs [Fuel/Gas]	63	405	578	250	351	403	536	465	77	0	-----	-----	-----	-----
OR-Besòs 3 and 4 [CHP]	0	0	0	0	0	0	0	1,627	3,568	4,872	4,254	4,970	4,655	4,728
OR-Badalona II [Fuel]	4	0	0	0	0	0	0	0	0	-----	-----	-----	-----	-----
Ordinary regime total production [BESÒS ENVIRONMENT]	**223**	**444**	**789**	**593**	**820**	**994**	**1,519**	**3,295**	**4,207**	**5,451**	**5,294**	**5,249**	**4,816**	**4,907**

FIGURE 77 | EVOLUTION OF THE IMPORTANCE OF ELECTRICITY PRODUCTION IN BARCELONA AND BESÒS WITH REGARD TO CATALONIA (ORDINARY REGIME)



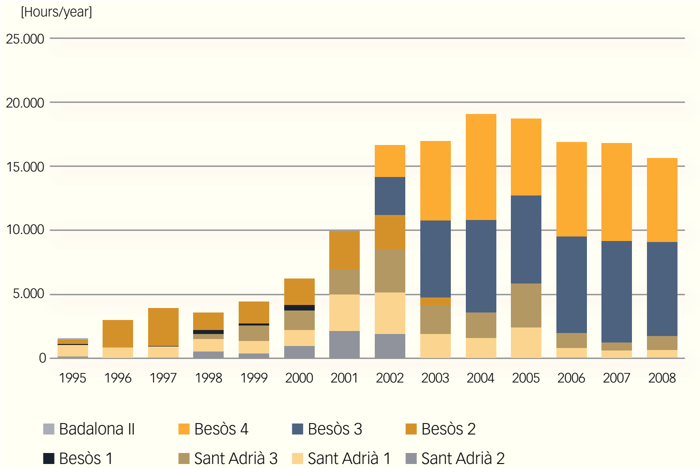
The energy production plants built over recent years (combined-cycles), despite having a lower output compared to the total installed output in Catalonia, produce a larger amount of electricity as they operate more hours.

FIGURE 78 | INSTALLED CAPACITY AND ENERGY PRODUCTION BY GENERATOR UNITS (ORDINARY REGIME)



Source: Red Eléctrica de España

FIGURE 79 | REAL OPERATING HOURS OF THE DIFFERENT GENERATOR UNITS (ORDINARY REGIME)

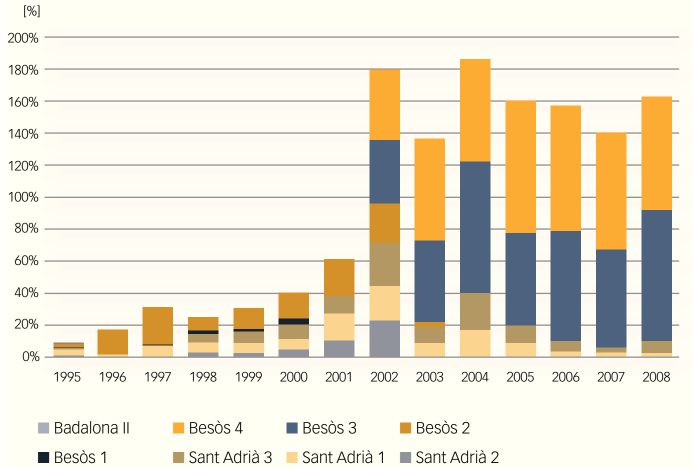


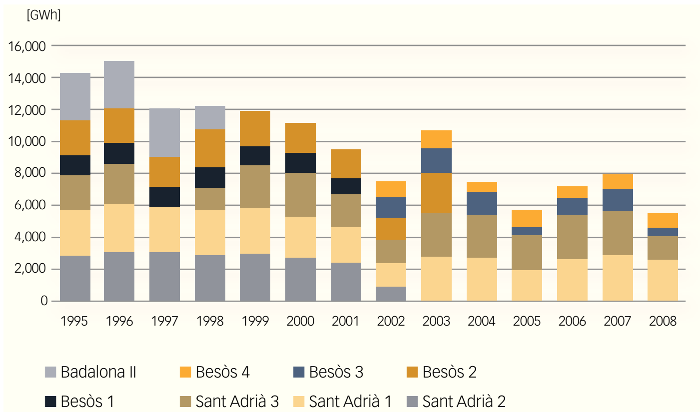
Source: Red Eléctrica de España

The real operating hours of the various energy units increased significantly between 2002 and 2008, as the new combined-cycle units were in operation for more hours to meet the higher electricity demand. In 2008, the Besòs 3 and 4 units operated for 7,469 hours and 6,635 hours respectively.

As regards the usage according to the available production (i.e. the quotient between the real production and the available production or maximum production achieved by the plant operating at nominal output during the hours it is functioning), the two combined-cycles at Besòs 3 and 4 totalled 82.1% and 70.8% respectively in 2008. This indicates that their *"surplus generation capacity"* is being reduced (available production minus real production).

FIGURE 80 | PERCENTAGE OF USE IN ACCORDANCE WITH AVAILABLE PRODUCTION (ORDINARY REGIME)





Source: Red Eléctrica de España

Production under the special regime

In addition to the ordinary regime facilities, Barcelona also has small electricity production plants which operate under the special regime of electricity generation (SR), which includes renewable energy sources and electricity and heat cogeneration processes. [16]Although several of these facilities are not located within the municipal boundary of Barcelona (such as the waste recovery plants) they must be taken into account when taking stock of the city's energy1. [17]This is the case of the power plant in Vall d'en Joan (the controlled landfill in Garraf, now closed) and of the three eco parks located within the metropolitan area (Eco park-1 in Barcelona, Eco park-2 in Montcada i Reixac and Eco park-3 in Sant Adrià), where electricity is obtained using the biogas generated during the decomposition of organic matter from municipal waste and the energy recovery plant in Sant Adrià, attached to the Eco park-3.

Most of the energy is produced in natural gas cogeneration plants (45.4%) and the solid waste recovery plant in Sant Adrià de Besòs (34.9%). Electricity was also produced using the biogas generated in the controlled landfill in Vall d'en Joan del Garraf (weighted energy of waste which was historically disposed of by the city of Barcelona compared to the total production in 2008), and the Eco park-2 (9.5%) and the sludge drying plant (Metrofang) (7.8%). The photovoltaic solar energy facilities (2.1%) and the mini-hydraulic plant in Trinitat (0.4%) account for lower, yet still significant percentages.

Over recent years, electricity production under the special regime totalled approximately 400 GWh a year, although this fell to 370 GWh in 2008 due to the reduction in production of the Metrofang cogeneration plant, coinciding with the change in the sludge drying technology.

16. These plants treat waste from the entire metropolitan area, so to ascertain the energy and GHG balance the same fraction of energy and emissions are assumed for Barcelona as the tonnes of city waste treated at the plant.

17. Eco Park 3 injected 167,504 MWh into the electricity grid in 2008 (obtained from incineration and energy recover from the waste) and 59,912 tonnes of steam to the district heating and cooling of the Fòrum (Districlima).

In the specific case of energy production at the controlled landfill in Vall d'en Joan del Garraf, it must be taken into account that no waste has been disposed of there since 2007. However, the generation of biogas continues, due to the methanisation of waste disposed of during previous years. Barcelona should be assigned part of this production together with the mean fraction of waste over the past four years' operation of the facility.

FIGURE 81 | DISTRIBUTION OF THE ELECTRICAL ENERGY PRODUCED IN BARCELONA AND THE BESÒS AREA, BY FACILITY, 2008 (SPECIAL REGIME)

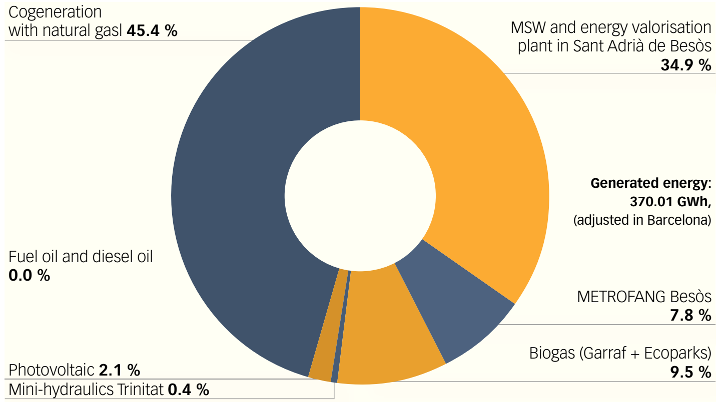


FIGURE 82 | EVOLUTION OF THE ELECTRICAL ENERGY PRODUCED IN BARCELONA AND THE BESÒS AREA 1999-2008 (SPECIAL REGIME)

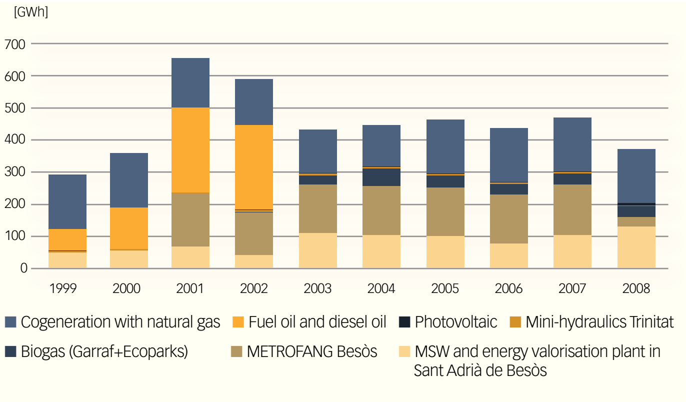


TABLE 25 | EVOLUTION OF ELECTRICITY PRODUCTION IN SPECIAL REGIME FACILITIES, 1999-2008

Special regime [GWh]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
MSW valorisation in Sant Adrià de Besòs	47.51	54.18	66.57	40.45	108.65	103.04	99.30	76.45	102.86	129.23
METROFANG Besòs	0.00	0.00	163.23	132.00	151.97	151.97(*)	151.97(*)	151.97(*)	156.65	28.81
Biogas (Garraf+Ecopark)	0.00	0.00	0.00	2.66	28.40	54.95	36.08	32.58	35.57	35.04
Mini-hydraulics Trinitat	6.22	5.71	5.16	6.30	6.13	5.11	5.11(*)	5.11(*)	3.34	1.47
Photovoltaic	0.003	0.024	0.046	0.130	0.158	0.758	1.01	1.23	1.45	7.62
Cogeneration with fuel oil and diesel oil	68.00	128.00	264.00	264.00	0.00	0.00	0.00	0.00	0.00	0.00
Cogeneration with natural gas	169.33(*)	169.33	153.71	141.76	135.21	128.62	167.85	167.85(*)	167.85(*)	167.85(*)
Special regime total production [BCN + BESÒS ENVIRONMENT]	**291.06**	**357.25**	**652.72**	**587.29**	**430.53**	**444.44**	**461.31**	**435.18**	**467.72**	**370.01**

* Estimates

Own consumption of locally produced electricity

If we consider both production under the ordinary regime (OR) and under the special regime (SR) in Barcelona and the Besòs area, the electricity produced in 2008 totalled 5,277,01.2 GWh (93% in OR and 7% in SR).

Own production of electricity in the territory increased without interruption until 2004, the year when production in the Besòs area started to fall due to the two new combined-cycles in Tarragona coming into full production. When these combined-cycles were commissioned, own consumption had reached a maximum of 81%, but this subsequently fell by 13 points in 2008.

Barcelona and the Besòs area therefore produce 68% of the electricity the municipalities of Barcelona and Sant Adrià de Besòs consume on an annual basis, i.e. it is necessary to import 32% of the electricity per year.

Barcelona and the Besòs area therefore produce 68% of the electricity the municipalities of Barcelona and Sant Adrià de Besòs consume on an annual basis, i.e. it is necessary to import 32% of the electricity per year

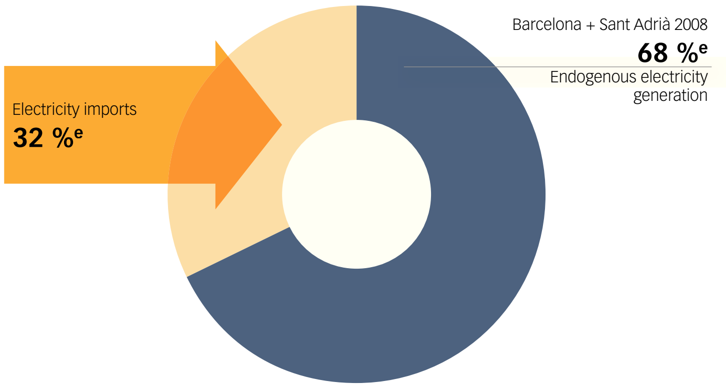
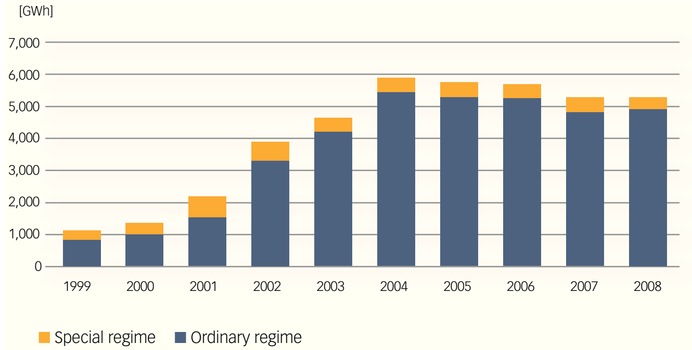


FIGURE 83 | EVOLUTION OF TOTAL ELECTRICITY PRODUCED IN BARCELONA AND THE BESÒS AREA 1999-2008 (SPECIAL AND ORDINARY REGIMES)



Source: Red Eléctrica de España and Barcelona Energy Agency

FIGURE 84 | EVOLUTION OF ELECTRICITY CONSUMPTION IN BARCELONA AND THE BESÒS AREA COMPARED TO PRODUCTION, 1995-2008 (SPECIAL REGIME AND ORDINARY REGIME)

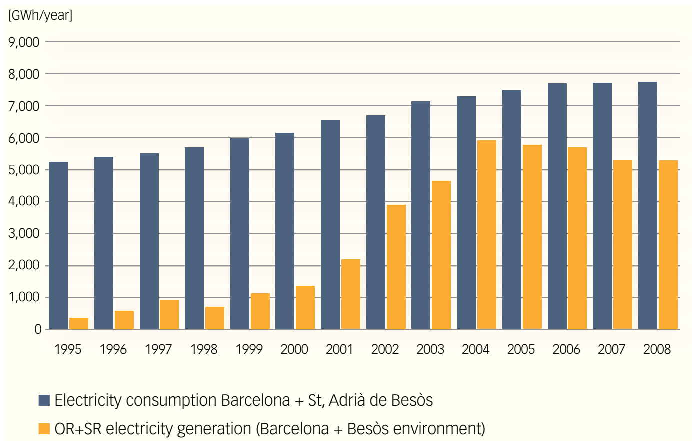
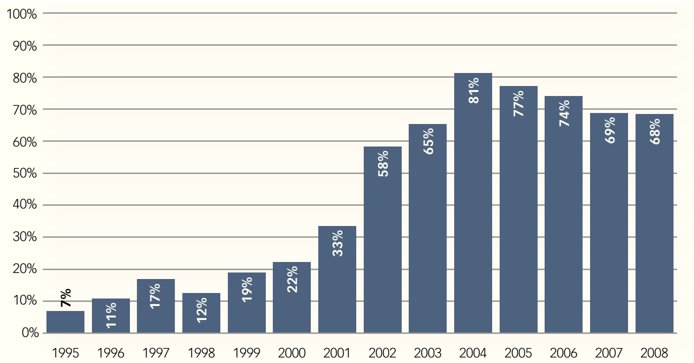


FIGURE 85 | EVOLUTION OF OWN ELECTRICITY CONSUMPTION IN BARCELONA AND THE BESÒS AREA COMPARED TO PRODUCTION, 1995-2008 (SPECIAL REGIME AND ORDINARY REGIME)



2.3.3 - EFFICIENT PRODUCTION SYSTEMS

The special regime not only includes renewable technologies for electricity production but also, as mentioned above, efficient production systems such as cogeneration and micro-generation or waste-to-energy recovery.

Cogeneration

Cogeneration refers to efficient, simultaneous production of heat and electricity. This technology is the most efficient of all fuel based production systems based on fuels, using gases (natural gas, biogas), liquid fuels (fuel-oil, gas-oil, LPG) or solid (coal, biomass, municipal waste). The generation occurs in alternate motors, gas turbines, steam turbines or fuel cells. Cogeneration can be implemented in all industrial or service sector industries which consume thermal energy.

In Barcelona there are various cogeneration plants in operation (both in hospitals and in different industries) which chiefly use natural gas as a fuel. These plants, together with the energy-to-waste recovery facility in Besòs, produced over 325 GWh of electricity in 2008.

In industry, cogeneration has been implemented in most sectors which require large amounts of heat (paper, chemicals, ceramics, etc.) and therefore those in which energy is an important production cost factor. Technically, the services sector is also highly suited for this technology although certain matters should be taken into account:

- It is advisable to take maximum advantage of the residual energy, by preventing it dissipating into the atmosphere.
- For cogeneration projects to be economically viable, the number of hours operation of the facility should be as high as possible.
- It should be remembered that in certain types of building, it may come into conflict with the solar thermal Ordinance.

The high efficiency of cogeneration systems is achieved by taking advantage of the heat generated by electricity production. The installation is sized in accordance with the heat flux used in the climate control of the building or buildings, while the electrical flux is circumstantial.

This heat can be used by passing it to a single consumer who requires it to meet the demand for heat and/cooling - saving on primary energy from other energy resources – or it can be distributed to a climate control network, District Heating and Cooling, making the system even more efficient.

District heating and cooling of the Fòrum and 22@

Barcelona has, for several years, opted to foster centralised climate control, as greater centralisation of heating and cooling improves performance and increases the efficiency.

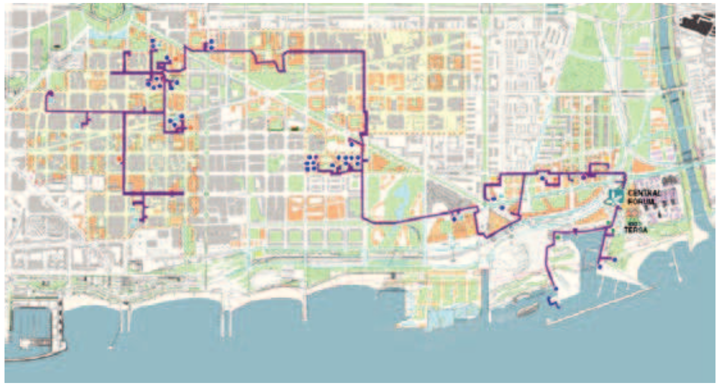
There is currently a centralised climate control network in the Fòrum and district 22@, under the management of Districlima, which operates by using the residual heat from the waste energy recovery plant in the Besòs (TERSA). There is another under construction in Zona Franca and La Marina del Prat Vermell - by the company Ecoenergies-, using biomass and residual cold from the regasification plant in the Port of Barcelona.

Barcelona has, for several years, opted to foster centralised climate control, as greater centralisation of heating and cooling improves performance and increases the efficiency.

The heating and cooling network of the Fòrum was the first to come into operation in Barcelona during the urban development stage of this area in 2004, and it continues to expand. Most users connected to the system pertain to the services sector, although public residential buildings are also adopting this energy. For energy support, the plant has high-efficiency heating and cooling equipment to ensure a continuous supply for system users.

The energy balance of the centralised climate control system of the Fòrum-22@, as a whole, represented a consumption of TERSA's residential heat of 34,895 MWh in 2009, gas consumption with auxiliary energy of 940 MWh and electricity consumption of 9,92777 MWh. Thus, 95% of the heat and 19% of the cold supplied originated from the residual heat of the TERSA plant, achieving a primary energy saving of 39,403 MWh/year and a reduction in CO_2 emissions of 7,076 t/year (51% and 58% respectively, compared to conventional systems). This network is still not complete, as it is in the process of expanding and growing within the area of the Fòrum and district 22@.

FIGURE 86 | DISTRICT HEATING AND COOLING OF THE FÒRUM AND DISTRICT 22@



Cooling power: 63.8 MW | Heating power: 41.3 MW | Number of buildings: 57 | Km: 12.0

Clients in operation:

Hotels / Residences | Offices | Dwellings | Commerce | School centres | Other

Source: Districlima

TABLE 26 | CHARACTERISTICS OF THE DHC NETWORK OF THE FÒRUM AND 22@

Characteristics of the DHC network of the Fòrum and 22@ (2009)		
	FÒRUM	22@
Network extent (km)	4.3	7.7
Number of clients	22	28
Subscribed heating power (kW)	22,415	14,793
Subscribed cooling power (kW)	31,842	25,925
Installed heating power (MW)	40*	
Subscribed cooling power (MW)	39*	
Demanded heating power (MWh/year)	14,482	6,685
Demanded cooling power (MWh/year)	20,499	20,364

Source: Districlima

(*) This output is currently installed at the Fòrum plant and construction has commenced on a plant in Carrer Tànger (22@)).

DISTRICT HEATING AND COOLING)

District Heating and Cooling is an energy distribution system in the form of hot and cold water for climate control, hot water and industrial processes which require heating or cooling. It is distributed via underground pipework in the city, industrial or service sector estates and groups of buildings such as airports or hospitals.

The DHC networks comprise the following:

- Energy production plant: where the centralised production of hot and cold water is generated using efficient conventional technologies or renewable energies.
- Distribution network: this comprises the pipework which must be perfectly insulated to ensure a good supply. It is the hub between the production plant and points of consumption.
- Points of consumption: heat exchangers are installed in the thermal substation to transmit the energy from the primary to the secondary circuit. This is used to supply heating, cooling and hot water.

This technology offers a reliable, efficient and economically viable means for the climate control of buildings. The facility will produce more or less global pollution depending on how the hot and cold water is generated at the production plant. The most recommendable means is via the use of renewable energies (chiefly biomass) or cogeneration. DHC systems help to cut down emissions and save energy..

2.4 - Renewable energies

2.4.1 - GLOBAL GENERATION

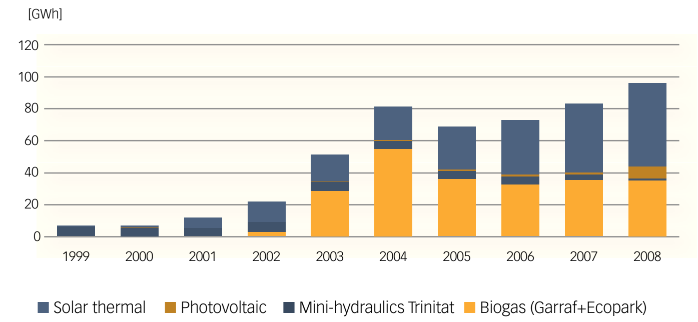
Renewable energy production in Barcelona saw a significant increase between 2003 and 2008 up to a maximum of 96.53 GWh, 0.57% of all the energy consumed (electricity, natural gas, automotive fuel and LPG). The energy sources used for this production were photovoltaic energy, solar thermal, small-scale hydraulics (Trinitat plant) and biogas (the proportional part of the gas produced at the controlled landfill in Vall d'en Joan del Garraf which corresponds to Barcelona and the treatment of waste from the eco parks).

If we consider solely the electricity produced using renewable sources produced in Barcelona (with biogas, photovoltaic solar and small hydro plants), with regard to overall electricity consumption in the city, the percentage in 2008 was 0.59%..

TABLE 27 | EVOLUTION OF ENERGY PRODUCTION USING RENEWABLE SOURCES IN BARCELONA, 1999-2008

Renewable energies [GWh]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Electricity with biogas (Garraf + Ecopark)	0.00	0.00	0.00	2.66	28.40	54.95	36.08	32.58	35.57	35.04
Mini-hydraulics Trinitat	6.22	5.71	5.16	6.30	6.13	5.11	5.11 (*)	5.11 (*)	3.34	1.47
Photovoltaic	0.003	0.024	0.046	0.130	0.158	0.758	1.009	1.227	1.453	7.620
Solar Thermal	0.464	0.664	6.410	12.633	16.560	20.846	26.842	34.155	43.299	52.405
Total renewables production	**6.68**	**6.40**	**11.62**	**21.72**	**51.25**	**81.66**	**69.03**	**73.07**	**83.66**	**96.53**
Renewable energies [m^2]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Solar Thermal	580	830	8,013	15,791	20,700	26,058	33,552	42,694	54,123	65,506

FIGURE 87 | EVOLUTION OF ENERGY PRODUCED USING RENEWABLE ENERGIES, BY ENERGY SOURCE IN GWH AND PERCENTAGE (1999-2008)



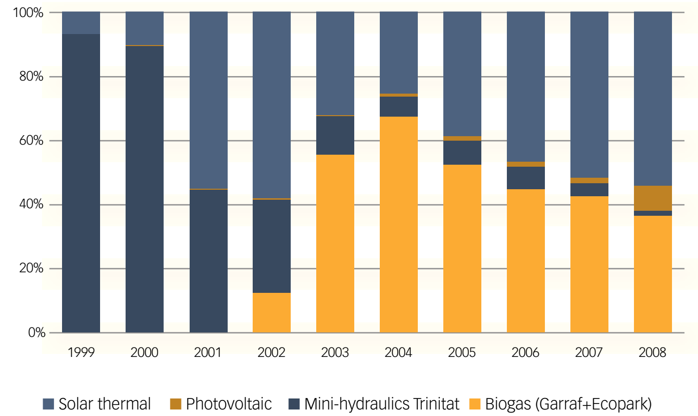
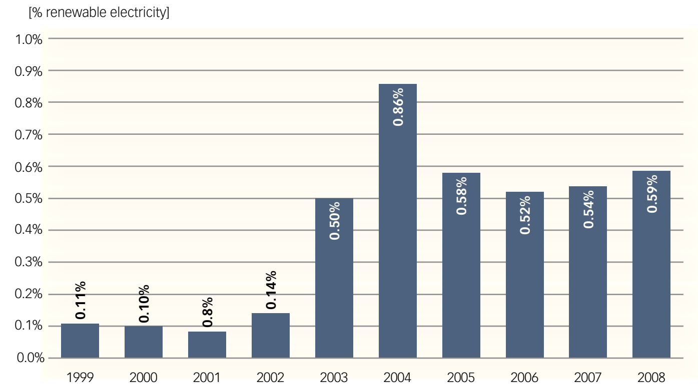


FIGURE 88 | EVOLUTION OF GLOBAL ELECTRICITY PRODUCED USING RENEWABLE ENERGIES, IN GWH AND PERCENTAGE (1999-2008)



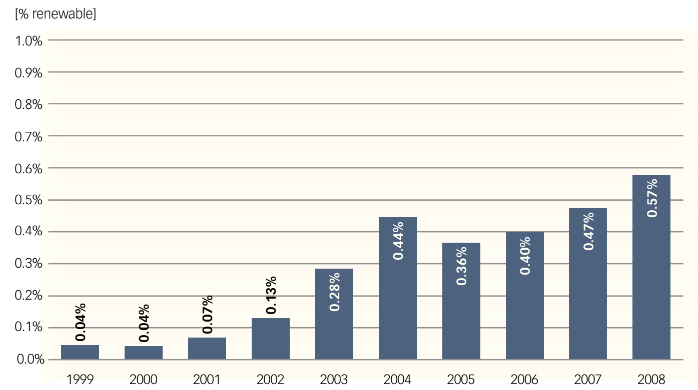


FIGURE 89 | % OF ELECTRICITY PRODUCTION USING RENEWABLE SOURCES IN WITH REGARD TO THE CITY'S ELECTRICITY CONSUMPTION

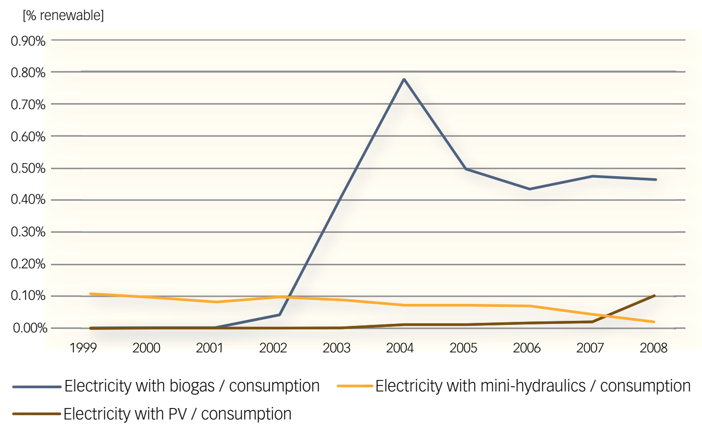
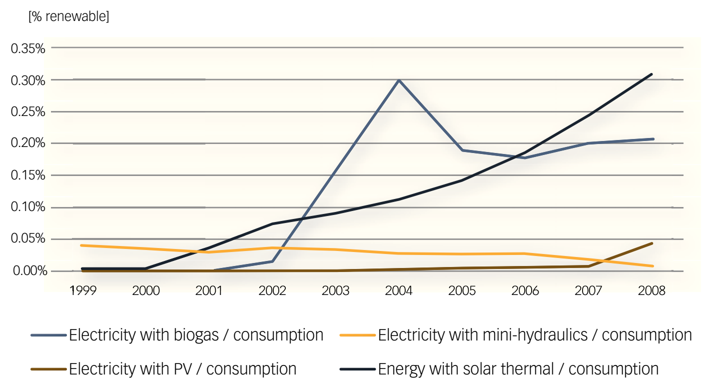


FIGURE 90 | % OF ENERGY PRODUCTION USING RENEWABLE SOURCES IN WITH REGARD TO THE CITY'S ENERGY CONSUMPTION



2.4.2 – SOLAR THERMAL ENERGY

The evolution of surface area for solar thermal energy

Solar energy is the chief renewable resource of the city, and solar thermal energy emerges as the most widely used renewable energy in the city, accounting for 52% of the total renewable production.

This is chiefly due to the boost it received from Barcelona City Council which, in 1999, in a plenary session, approved the solar thermal capture appendix to the general environmental Ordinance, known as the Barcelona Solar Thermal Ordinance (OST). For the first time, a regulation was approved which made it compulsory for new buildings and those under refurbishment to incorporate solar energy systems to meet the demand for hot water.

In 2002, Barcelona City Council also approved the Energy Improvement Plan of Barcelona (PMEB) which undertook to increase energy production using renewable sources of primary energy, especially solar thermal energy. It also established the objective of reaching 96,300 m² of solar thermal panels by the year 2010.

The Ordinance was approved and has been implemented during these years within a context of a growing economy, a greater built-up surface area and energy consumption.

During these years, Barcelona has grown in reach and built-up surface area, forming an increasingly complex city. [18][19]During these ten years, over 2,500,000 m² of land space has been built1, especially in housing, garages and car parks and the services sector (shops, offices and hotels) with an accumulated growth rate of 0.33% per year1. The new urban fabric is

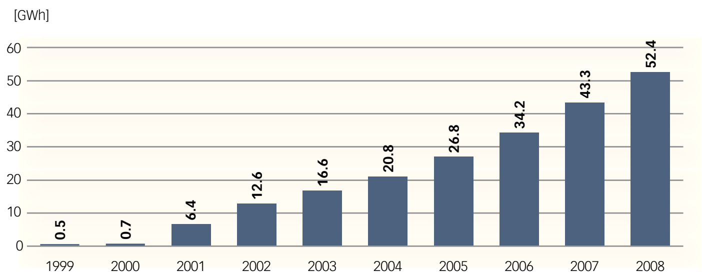
18. According to the Land Register and IMI data, in 1999 in Barcelona there were 107,349,390 m² of land space, while in 2006 there were 109,843,343 m².

19. These figures do not include those buildings which were built to replace older land space. An analysis of buildings built after 1999 shows almost 5 million m².

currently being developed via land reutilisation, as there is practically no available land, signifying that major urban projects are carried out by reassigning land use.

In both cases, the new built-up surface area has meant that solar thermal energy has spread throughout the urban fabric, to a figure of 65,506 m^2 of solar surface authorised in 2008, 2,687 m^2 of voluntary installation as a result of the implementation of the OST.

FIGURE 91 | EVOLUTION OF SOLAR THERMAL SURFACE AREA IN BARCELONA (1999-2008)



Source: Barcelona Energy Agency

Balance of the Solar Thermal Ordinance[20]

The first appendix to the General environmental Ordinance on Solar Thermal Capture, also known as the *"Solar Ordinance"*, was approved and published in July 1999 (BOP no. 181 / page 25-27, dated 30/7/99) and came into force in August 2000, one year after publication due to a moratorium agreed between the Council and other players involved in its implementation.

Before the Solar Thermal Ordinance came into effect, Barcelona had seen several attempts to encourage the installation of thermal systems for solar energy, such as the campaign launched by Barnamil, the financial assistance under the *"Barcelona posa't guapa"* campaign, etc. These did not, however, have any significant impact, except the initiative of the Municipal Housing Board, with the social housing projects in Vores de les Rondes, where a total of 750 m^2 of solar thermal panels were installed. This initiative was carried out in parallel to the approval of the Solar Ordinance during the year's moratorium and acted as a pilot test of the application of the Ordinance.

Thus, at the time the Solar Ordinance came into effect, the solar thermal surface installed in the city covered 1,650 m^2, mostly promoted by the local government.

20. Balance of the Solar Thermal Ordinance1Agència d'Energia de Barcelona. Barcelona Energy Agency

Following the approval of the Barcelona Energy Improvement Plan in 2002 (PMEB), the implementation of the Solar Ordinance was monitored to ascertain the extent to which the ordinance was accepted, to record the number of installations and square metres installed, and to monitor the condition of the installations and their operation.

The experience of the local government during the initial years of the Solar Ordinance and the resulting identification of its strong and weak points led to the text of the Ordinance being reviewed. This revision was carried out between 2004 and 2005, and in addition to the municipal experience, it took into account that of other towns and cities which had implemented this regulation within their municipalities.

[21]In 2005 a debating table was formed, called the Solar Table20, for the purpose of debating the implementation, needs for improvement and the amendments to be made to the text of the Ordinance and which approved the definitive text.

The new drafting of the Ordinance introduced amendments as regards appropriation, making exemptions more restrictive, the quality of the facilities, setting out the conditions for certification and the technical criteria for maintenance and use of same and their harmonisation with other regulations on a national or autonomic scale.

The introduction of the Ordinance

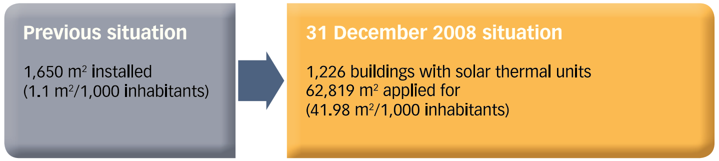
As a result of the solar Ordinance, until 31 December 2008, 1,226 buildings have been forced to install solar thermal capture systems for hot water production, with a total solar thermal surface of 62,819 m^2.

[22]The solar energy installations which are compulsory under the Ordinance are estimated to produce an energy saving of 50,255 MWh/year21,

The housing and residential sector is that with the highest percentage of solar surface processed, with 69% of the total surface used for solar thermal capture in the city, followed by hotels, with 16% of the total.

The result of the application of the Solar Thermal Ordinance as regards the number of buildings affected since it came into effect in 2000, has been one of sustained growth during the years since. There was, however, a turning point in 2006 caused by the larger number of buildings involved, a direct result of the high number of buildings constructed during the years 2006, 2007 and 2008.

FIGURE 92 | **EVOLUTION OF SOLAR THERMAL ENERGY IN BARCELONA**



21. The agents who took part in the Solar Table were:the Association of Building Engineers and Technical Architects, the School of Industrial Engineers of Catalonia, APERCA, the Spanish Association of Solar Energy and Alternative Energy Companies, ASENSA, the School of Property Administrators of Barcelona, the Association of Developers and Builders of Barcelona, the Consumer and User Organization of Catalonia, the Association for the promotion of renewable energies and energy saving, BARNAMIL, the Municipal Institute of the Urban Landscape and Quality of Living, the Municipal Housing Board, the School of Architects of Catalonia, Barcelona City Council, The Catalan Energy Institute, the Fitters Guilds of Barcelona, FERCA and the Barcelona Energy Agency.

22. A final energy production of 800 kWh/m^2 has been assumed for the solar thermal capture area. Source:Pla de millora energètica de Barcelona. Barcelona Energy Improvement Plan.2002.

FIGURE 93 | DISTRIBUTION OF THE SOLAR THERMAL SURFACE AREA BY USE (2008)

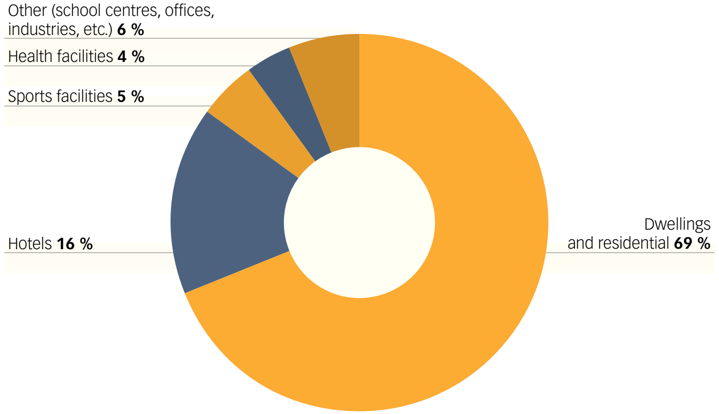
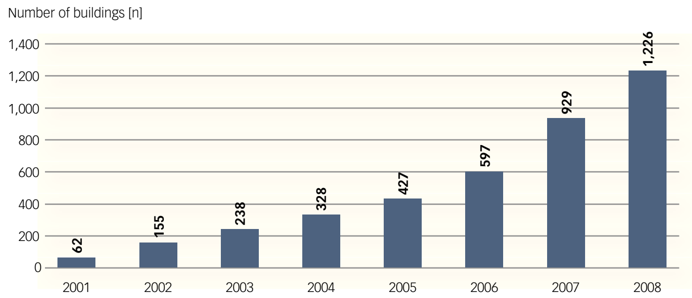


TABLE 28 | DISTRIBUTION OF THE NUMBER OF BUILDINGS AND SOLAR THERMAL SURFACE AREA BY USE (2008)

Type of use	Number of buildings with ST	Solar collectors' area [m²]
Dwellings and residential	959	43,231
Hotels	115	10,198
Sports facilities	20	3,125
Health facilities	25	2,223
Other (school centres, offices, industries, etc,)	107	4,4041
Total	**1,226**	**62,819**

FIGURE 94 | EVOLUTION OF THE NUMBER OF BUILDINGS AFFECTED BY THE OST (2001-2008)

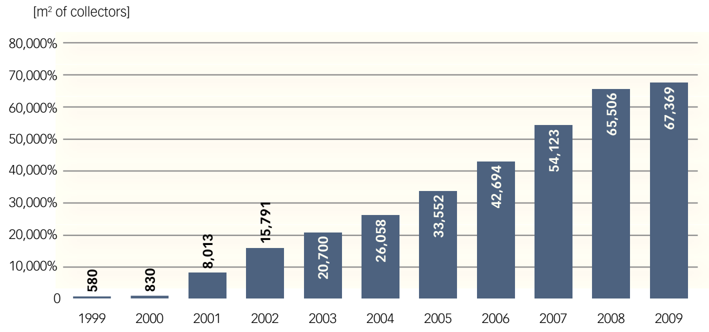


Between 2006 and 2007 there was a change of trend as regards the number of buildings affected by the new regulations, which almost doubled. The evolution of the solar surface, on the other hand, did not continue the same trend and the increase was not as marked as expected.

This is mainly due to the fact that most of the new buildings which are obliged to incorporate solar thermal systems are small, and therefore the solar surface does not have a significant effect on the total surface for the remaining types of buildings which the previous regulations already took into account.

The considerable increase in the solar thermal capture surface as a result of the solar Ordinance, in addition to the surface area installed prior to the solar Ordinance and the facilities built but unrelated to it, chiefly at the initiative of Barcelona Council, signify that the solar thermal surface installed or planned exceeds 65.506 m². This is forty times the surface area prior to the solar Ordinance.

FIGURE 95 | EVOLUTION OF TOTAL SOLAR THERMAL SURFACE AREA (1999-2009)



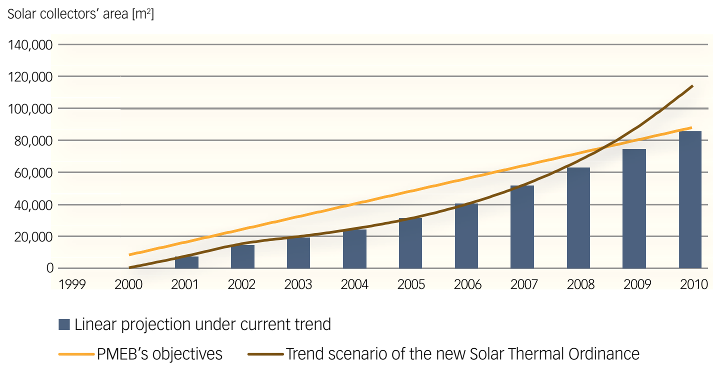
The solar capture surface in proportion to the current population of Barcelona is 41,98 m²/1,000 inhabitants, a significant figure given the ratio prior to the OST (1.1 m²/1,000 inhabitants) and which is in line with the rest of Europe and far in excess of the national average.

It should be remembered that the Barcelona Energy Improvement Plan (PMEB) established a target of 96,300 m² of solar thermal panels installed in the city by 2010, with a planned thermal production of 77,810 MWh/year (280,000 GJ/year). Of this surface area, it was estimated that 88,015 m² of solar capture would be installed as a result of the solar thermal Ordinance.

With the amendment and implementation of the Ordinance in mid-2006, which eliminated the limits on its application, the number of buildings obliged to install solar thermal energy systems was expected to increase to well over the surface targeted in the PMEB. In view of the results achieved during 2007 and 2008, we can see that this is not the case, as the number of homes currently affected in respect of the surface area are very few.

Despite this, according to the figures for 2010, the aims set forth in the PMEB to install 88,015 m² of solar thermal panels has almost been achieved by the solar thermal Ordinance, as at 31 December 87,600 m² had been implemented.

FIGURE 96 | COMPARISON BETWEEN THE REAL TREND OF EVOLUTION OF THE OST AND THE TREND FORESEEN IN THE NEW OST



The implementation systems and challenges overcome

As mentioned earlier, the chief driver of the introduction of solar thermal energy in the city was Barcelona Council which, with clearly political motivations, approved a pioneering regulation which initially met with some rejection and mistrust among the various players involved in its implementation, all of which led to a one-year moratorium being put in place prior to its implementation.

Initially, the pioneering nature of the solar Ordinance also presented certain dysfunctional ties as regards its implementation due, on the one hand, to the Council's virtual lack of experience in drafting and applying a regulation of these characteristics (especially when specifying the exemptions) and on the other, to the lack of legal references for the formulation of the text and protocols.

The application of a regulation which makes it compulsory to introduce a new element in buildings, with the particular characteristics of solar energy installations, obliged the Council to put in place appropriate management systems to monitor compliance with the Ordinance and follow up its evolution within the city.

Thus, the Council, via the Barcelona Energy Agency sought the necessary instruments to define and put in place case review procedures and protocols, defining the administrative circuit to be followed so as to ensure the success of the solar thermal installations at every stage, from the planning phase to implementation and throughout their useful life.

These management instruments have culminated with the launch of an online processing management site for planned solar thermal installations which, placed at the disposal of the chief players, developers, designers and supervisors of solar thermal installations, seeks to furnish them with the necessary knowledge regarding the processing and standardisation of design criteria and formulation of projects to comply with the OST, optimising the administrative procedures and speeding up the formalities.

The initial moments of the pioneering solar Ordinance were difficult, giving rise to controversy and strong rejection from a part of the sector. The one year moratorium approved is a clear indication of this situation. The mistrust was not without grounds, as recent experience in Spain was minimal and the sector still recalled the failed experiments in the sector in the seventies.

It is also true (and this has been acknowledged by all the players involved - from the Administration, developers and technicians responsible for drafting the projects to the fitters) that the sector was not prepared to confront the challenge with any guarantee of success, and much uncertainty still surrounded the approval of this new ordinance, which required solar installations be fitted to all new buildings in the city of Barcelona.

Today, in hindsight, and after analysing the results achieved, it is evident that the inexperience led to errors in the installations, resulting in the correction and updating of certain loopholes in the Ordinance, such as the monitoring and maintenance of the installations in the amendment of 2006.

Moreover, the chief barriers to the development and application of the Ordinance are also its chief support. The implementation of the Ordinance is clear evidence that it is not possible to wait until sufficient experience has been acquired for such an important and significant undertaking as this, as sufficient progress would never have been achieved. Difficulties have been overcome or solutions are in progress and there exists a consensus that the operability and effectiveness achieved with the effort of all involved have made it possible to standardise solar thermal energy facilities.

The Solar Thermal Ordinance of Barcelona should be viewed as an essential step towards the standardisation of solar thermal energy in Spain, yet a simple, local measure cannot be expected to offer more than this. However, its impact has been clearly greater than that imagined when it was approved.

The Solar Thermal Ordinance of Barcelona should be viewed as an essential step towards the standardisation of solar thermal energy in Spain, yet a simple, local measure cannot be expected to offer more than this. However, its impact has been clearly greater than that imagined when it was approved

The new challenges: revitalising solar thermal energy

Although solar thermal energy is now a reality in Barcelona, its day-to-day management and the use and maintenance of the current facilities still present challenges.

The objective, for the future, is to ascertain the condition of the installations executed under the OST. Aside from the surface area installed, it is necessary to ascertain how many installations operate correctly, to what extent they contribute to energy saving and what issues or difficulties users encounter during the life of the facilities. This knowledge should be used to define strategies and courses of action with a view to ensuring proper operation of the facilities and optimisation of solar power.

Another major challenge is to incorporate solar systems into pre-existing buildings, to which the Ordinance is not applicable. Therefore, new promotional measures must be put in place which are more effective than those taken to date.

Last but not least, the other matter pending in Barcelona regarding solar energy is to extend solar thermal systems for other uses (not only hot water), such as solar climate control, electricity production or injecting heat into district networks, using solar concentration technologies for these purposes.

Given its magnitude and potential for energy saving, these are the challenges for the coming years in the field of solar thermal energy in Barcelona. Together with the approval of the photovoltaic solar Ordinance, they will extend solar energy even further, increasing the production of renewable energy in the city.

2.4.3 – SOLAR PHOTOVOLTAIC ENERGY

The installed photovoltaic capacity in 2008 in Barcelona totalled 6,116.5 kWp; 27% in municipal areas and the remainder (73%) in private areas.

This figure is a major step forward compared to previous years, when the output was 296 and 832 kWp respectively. This increase is caused firstly by the municipal policies and actions to promote renewable energies, such as the launch of the initial phase of the photovoltaic structure in the Fòrum (which signified multiplying the total installed capacity in 2003 almost threefold), the installation of facilities in schools and, more recently, the introduction of 270 kWp more in municipal facilities and the completion of the second phase of the 650 kWp photovoltaic plant of the Fòrum.

Secondly, the increase was the result of the economic incentives for remuneration of photovoltaic installations on rooftops, which spurred the private sector to occupy numerous industrial roofs with photovoltaic panels. One example of this is the Barcelona Trade Fair which installed 1.2 MWp in 2008.

The energy produced by these installations in the aggregate in 2008 was 7.62 GWh, a figure which represents an annual increase of 226% since 2004.

FIGURE 97 | EVOLUTION OF THE TOTAL PHOTOVOLTAIC CAPACITY INSTALLED IN BARCELONA, BY OWNERSHIP (1999-2008)

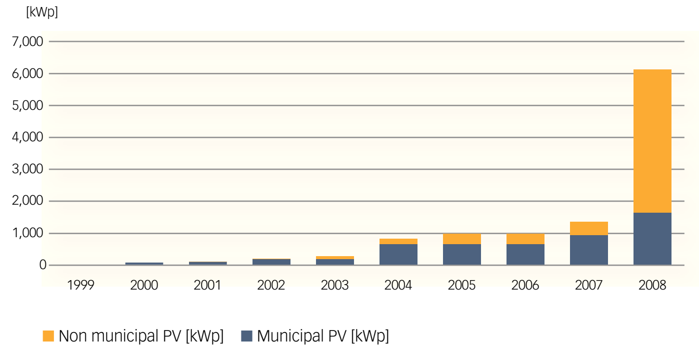


FIGURE 98 | EVOLUTION OF ENERGY PRODUCTION BY PHOTOVOLTAIC INSTALLATIONS IN BARCELONA (1999-2008)

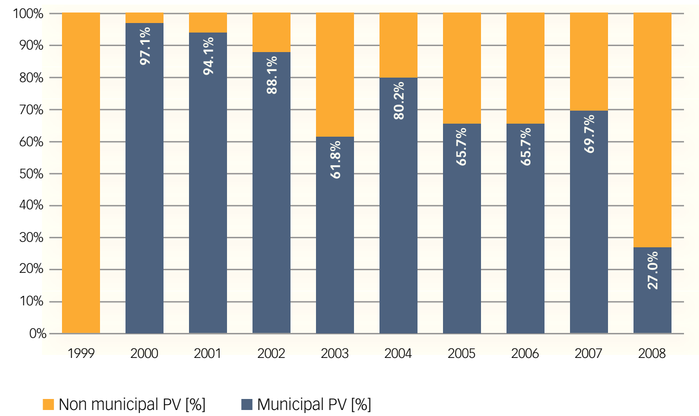


FIGURE 99 | EVOLUTION OF OWNERSHIP OF PHOTOVOLTAIC INSTALLATIONS IN BARCELONA (1999 – 2008)

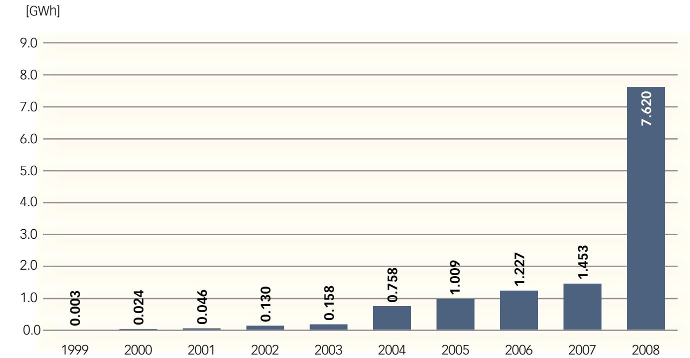


TABLE 29 | EVOLUTION OF ENERGY PRODUCED BY PHOTOVOLTAIC INSTALLATIONS IN BARCELONA (1999 – 2008)

FV [kWp]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Municipal PV [kWp]	0.0	85.2	120.4	183.1	183.1	667.1	667.1	667.1	947.7	1,649.0
Non municipal PV [kWp]	2.5	2.5	7.6	24.8	113.0	165.2	348.6	348.6	412.9	4.467.6
Total PV [kWp]	**2.5**	**87.7**	**128.0**	**207.9**	**296.1**	**832.3**	**1,015.7**	**1,015.7**	**1,360.6**	**6,116.5**

2.4.4 - BIOGAS

The network of eco parks where municipal waste is treated in Barcelona and its metropolitan area (Eco park-1 in Barcelona, Eco park-2 in Montcada i Reixac and Eco park-3 in Sant Adrià) generate biogas for energy use.

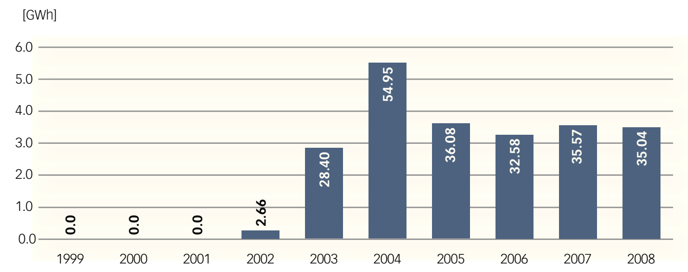
In 2008, 9,153 m^3 was generated by Eco park-2 in Montcada i Reixac and 1,125,394 m^3 by Eco park- 3 in Sant Adrià. 20,18 MWh of electricity was produced directly by Eco park-2 biogas while Eco park-1 in Barcelona produced none. Eco park-3 had indirect electricity production via the energy-to-waste recovery Plan in the Besòs as both facilities are attached.

It should be borne in mind that in the energy balance of Barcelona, electricity production is calculated proportional to the amount of organic waste transferred by the city to Eco park-2, and which in 2008 accounted for 11% of the total waste received. This represents 2.22 GWh of electricity.

As regards the controlled landfill in Vall d'en Joan (closed down in 2007, but which continues to produce electricity using the biogas produced during the decomposition of organic material disposed of years earlier), a proportional part of the total electricity production (55.21 GWh in 2008) is attributable to Barcelona. Therefore, the production of this facility is weighted at 59.44%, a percentage which corresponds to the amount of waste the city produced over recent years compared to the total waste disposed of at the site. In the energy balance, this represents an attributable electricity production of 32.82 GWh in 2008.

Thus, in 2008 a total of 35.04 GWh was generated.

FIGURE 100 | EVOLUTION OF ENERGY PRODUCED USING BIOGAS IN BARCELONA, (1999-2008)

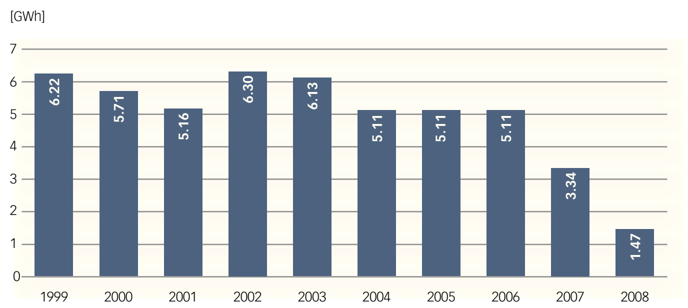


2.4.5 - SMALL SCALE HYDRAULIC FACILITIES

The energy produced by small hydro plants was 1.47 GWh (estimating the data from 2005 and 2006 using the production in 2004). The two years with the highest production were clearly 2002 and 2003.

In view of the rainfall of the Catalan basins which feed the small hydro-plant of Trinitat, it is not expected to exceed 6 GWh, although it will be necessary to see the data for 2009, which benefited from abundant rainfall.

FIGURE 101 | EVOLUTION OF ENERGY PRODUCED IN SMALL HYDRO PLANTS IN BARCELONA (1999-2008)



2.5 - The energy supply

2.5.1 - THE ELECTRICITY SUPPLY

The characteristics of the network

Barcelona is powered by the 400 kV network from the substations located in Sentmenat, Rubí, Pierola and Begues. 220 and 110 kV power lines from these four substations enter Barcelona mainly via the substations in L'Hospitalet, Santa Coloma, Sant Andreu and Besòs. The lines (aerial) and cables (underground) which currently form the electricity network of Barcelona are classified in line with their voltage:

- The high voltage (HV), with a total of 188 km, is formed by 220 kV (64%) and 110 kV (36%) cabling. Its chief purpose is distribution, even though given its voltage level it forms part of the transmission network.
- The medium voltage network (MV) is formed by 25 and 11 kV lines. The mesh and coexistence of these networks is the result of the three distribution companies which operated in Barcelona with different operating and maintenance criteria. The new lines are designed for 25 kV, but old 11 kV equipment continues to be replaced by new equipment with the same voltage.
- The low voltage network (LV), with total of 3,084 km, links the transformation centres with the end user. Different voltage levels also coexist: 220/127 V and 380/220 V, although the 220/127 V circuits are to be gradually replaced by 380/220 V to standardise them.

The non-standardized composition of the distribution network makes it complex to operate, especially the low voltage network, which has most impact on quality as perceived by the customer. The voltage transformation in Barcelona for users is carried out via twenty-two HV/MV substations with different distribution centres (DC) and the MV/LV distribution centres. The total transformation output currently installed in the area of Barcelona is 6,617 MVA.

In order to meet the new demand in the city, the planning of the transmission network provides for the creation of three new 400 kV substations in the Barcelona area (Viladecans, Santa Coloma de Gramenet and Sant Just Desvern), connection to the transmission network and the mesh between them and the current substations, all of which will supply the 400 kV network to the city. Eight new 220 kV substations are also planned to meet the new expected energy demand, to bring the supply points closer to the end user and to enhance the reliability and quality of the supply. The implementation of the new substations also includes the installation of new 220 kV lines (underground) to power them and create the mesh.

On the other hand, the approval of Law 18/2008 on the reliability and quality of the electricity supply in Catalonia sets out criteria for the creation of power lines which involve a modification and improvement of Barcelona's current electricity network. This law also states that 90% of the power supply of Barcelona must be channelled via two different substations.

The parameters for quality evaluation

In order to evaluate the quality of the electricity network, different indicators are used to measure the time and number of interruptions occurring and which affect the proper functioning of the power supply.

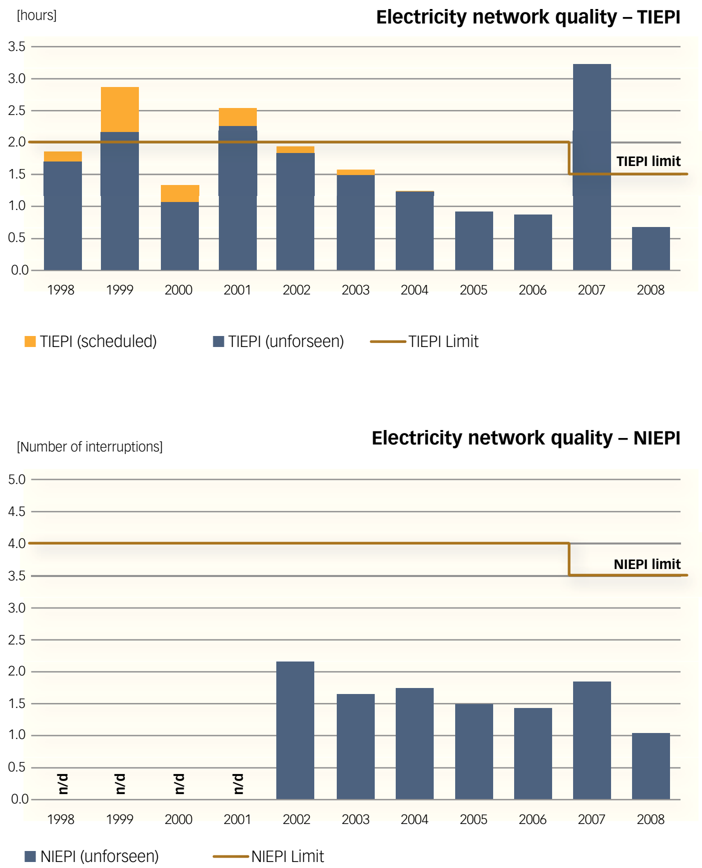
One of these indicators is the Interruption Time Equivalent to Installed Capacity which expresses the equivalent time during which all the installed capacity in a given area has been interrupted. This indicator can be programmed when the interruptions have been planned to carry out network maintenance work or other tasks, or can be random when unplanned interruptions occur due to system failures with regard to the installed capacity.

The evolution of this indicator in Barcelona has seen a downward trend over the past six years. Thus, in 2006 it had a level of 0.86 hours, below the service quality limit set forth in Royal Decree 1634/2006 which sets a limit of 1.5 hours for an urban area such as Barcelona (before, the limit was 2 hours, under Royal Decree 1955/2000). In 2007, this indicator underwent a sharp increase due to the blackout in July which left 330,000 subscribers without electricity during several days.

Another network quality indicator is the number of interruptions equivalent to the installed capacity. Its evolution in Barcelona has remained steady over recent years and at no time has it exceeded the service quality limit of four interruptions provided in Royal Decree 1955/2000 for the years prior to 2007, and three equivalent interruptions in Royal Decree 1634/2006 for 2007 and subsequent years.

When evaluating these data, it should be borne in mind that according to Order ECO/797/2002, only interruptions of over 3 minutes are recorded, for both indicators.

FIGURE 102 | EVOLUTION OF THE TWO EQUIVALENT INTERRUPTION INDICATORS IN BARCELONA (1999-2008)



Source: Department of Labour and Industry. Directorate General of Energy, Mines and Industrial Safety - Energy Supply Quality Service

Although Barcelona City Council is not responsible for electricity distribution and transport[23], it does participate in the Mixed Committee in monitoring the realisation of the investments contained in the five-year and annual investment plans in distribution and transmission facilities located in Barcelona (since the publication of the power supply reliability and quality law -LGQSE- in 2008).

Barcelona City Council, mindful of the importance of a high-quality service and power supply for the public and the economy, has various agreements with the distribution company which specify different actions to upgrade and improve the power network over the coming years.

When sizing the investment and improvement efforts of the power network, Barcelona Council considers it necessary to evaluate the quality of the power supply using different parameters, in addition to the Equivalent Interruption indicators:

- RELIABILITY OF THE SUPPLY
  The Interruption indicators reflect the quality of the service in relation with the number and duration of the interruptions, but the shortcomings of these indicators (for example, the level of aggregation) mean that they do not suffice to perform a suitable evaluation.
  These two indicators, as provided in current law, are grouped by municipalities, and therefore more accurate information must be available to obtain data on areas of customers who require more guarantees.

- RELIABILITY OF THE NETWORK
  This is the parameter which represents the probability of the system functioning correctly at any given moment. It is expressed as a percentage or the estimated unavailability time and is a key factor when making decisions on power network planning.
  Different indices can be used to evaluate the monitoring of this parameter, both for the current network and that planned for the future:
  - Failure rate (λ): number of annual failures occurring in an element.
  - Expected time to failure (ETTF): moment when the first failure of an element will occur.
  - Reliability (R): probability that an element functions correctly during a given time.
  - Probability of failure (Q): probability that an element does not function correctly during a given time.

- PRODUCT QUALITY OR QUALITY OF A VOLTAGE WAVE
  This parameter shows the probability of the voltage supplied remaining within acceptable perturbation limits. Long supply interruptions are not taken into account, however.
  Given that the quality of the voltage wave is not perceived or assessed uniformly by all users, it is necessary to evaluate its appropriateness in accordance with the impact on each customer so as to assess the need for, and justification of, a network investment vs. the cost of other systems to mitigate the effects of a wave alteration.
  The indices used to evaluate and monitor this parameter are as follows:
  - The average time outside the parameters of variations of the effective voltage value (-7% < UN < +7%).
  - The average number of brief interruptions (under 3 minutes).
  - The average duration of brief interruptions.

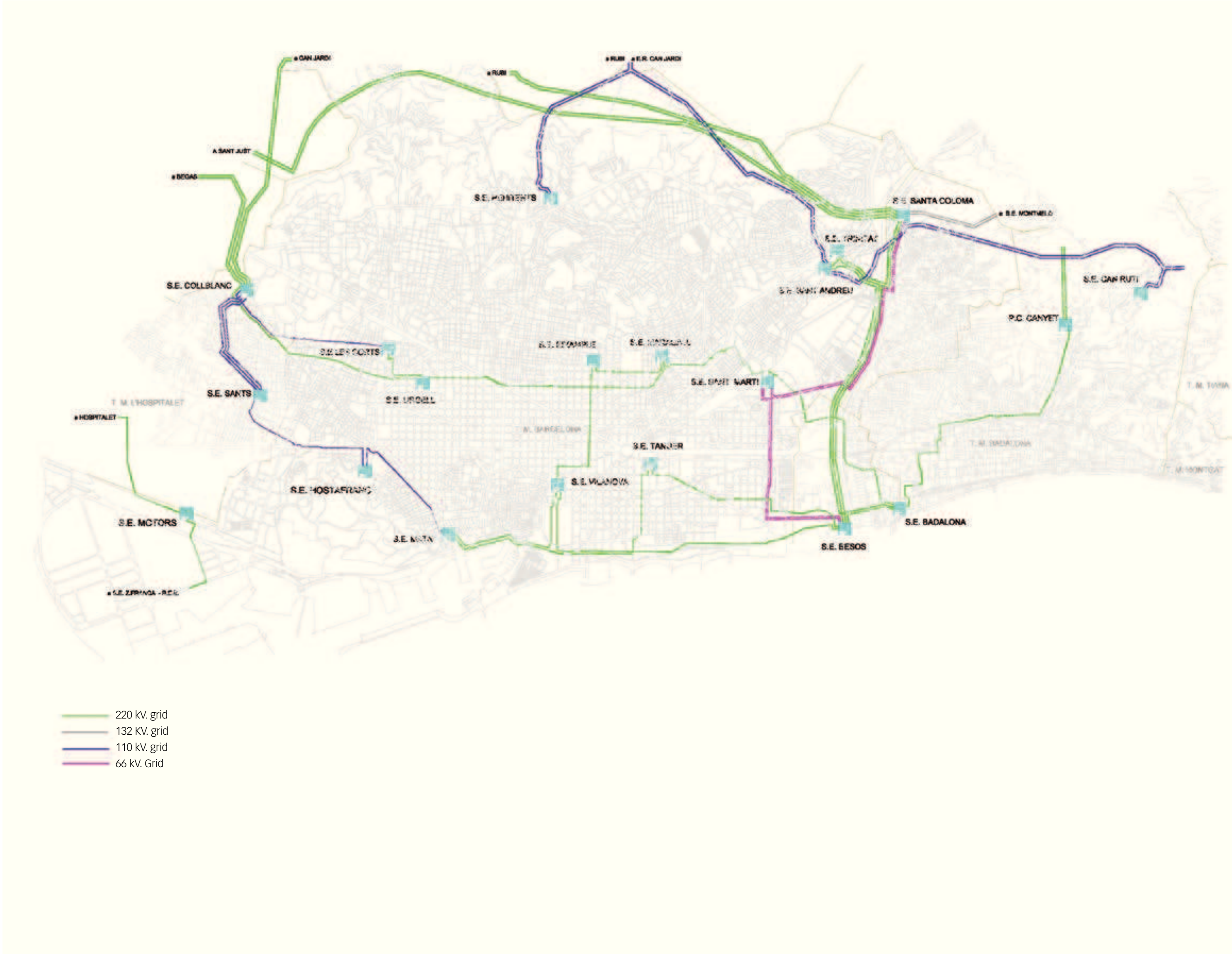
23. The National Government is the competent Authority in electric energy transport matters.The Planning of the Electricity and Gas Sectors 2008–2016, of the Ministry of Industry, Tourism and Trade provides for the implementation of transport networks throughout the country, including strategic actions planned in Barcelona.This document is scheduled to be revised to adapt it the pace of investments to the drop in demand. The Generalitat de Catalunya has the competencies in electrical energy distribution within the territory of Catalonia.

- CUSTOMER SERVICE QUALITY AND RELATIONSHIP WITH THE COMPANY
  The attention the customer receives and their relation with the company providing the services or future services has a significant influence on the overall perception of service quality. Electricity supply is no exception.
  For electricity, therefore, it is necessary to define the commercial quality as the user's perception of the degree of compliance or satisfaction with the electricity supply services, irrespective of the provider.
  Customer care services which condition the commercial quality can be evaluated in operations prior to contracting the supply and in operations during the supply contract. What is proposed is to create indices which reflect the commercial quality in an objective manner and which can be used to monitor the electricity companies.

- SUSTAINABILITY OF THE NETWORK
  These parameters seek to minimise the environmental impact when planning either improvements or enlargements of the electricity infrastructure network together with the electrical generation and consumption model.
  Defining network sustainability indices is necessary to answer questions such as:
  - Are the proposals and improvement or enlargement of the infrastructure appropriate from an environmental viewpoint? What action is being taken to minimise the impact?
  - What role do local generation and electricity distribution play in enhancing energy efficiency? What measures are being taken to avoid oversizing of the transmission network and help to contain the increase in electricity demand?

  How has the current electricity supply affected the general public's wellbeing? What inequalities are to be found in social and economic spheres due to the current supply conditions? How do customers assess the energy cost increase/supply quality increase ratio?
  In order to answer these questions, we propose initially evaluating seven sustainability indicators grouped into three types: environmental, efficiency and socioeconomic. With the data available to the Council, the following indices have been evaluated:
  - Environmental indicators: Appropriation of facilities and impact on land/subsurface.
  - Efficiency indicators: Local production and production using renewable energies.

FIGURE 103 | **HIGH VOLTAGE ELECTRICITY NETWORK OF BARCELONA**



2.5.2 - NATURAL GAS SUPPLY

The characteristics of the network

The total extension of the natural gas network in Barcelona is 1,553 km., of which 14 pertain to the small part of the transport network surrounding Barcelona and the remaining 1,539 km to the distribution network. 80% are low pressure and just 6%, high pressure.

Natural gas is distributed and transported via pressurised gas pipelines operating at different pressure ranges. The pressurisations are carried out at the regulation and measurement stations (RMS) and the regulation chambers (RC), equipment located in streets (aerial or underground) and designed so that the consumer receives the supply within a suitable pressure range (22 mbar for domestic consumption and different ranges for industrial consumption, depending on the process).

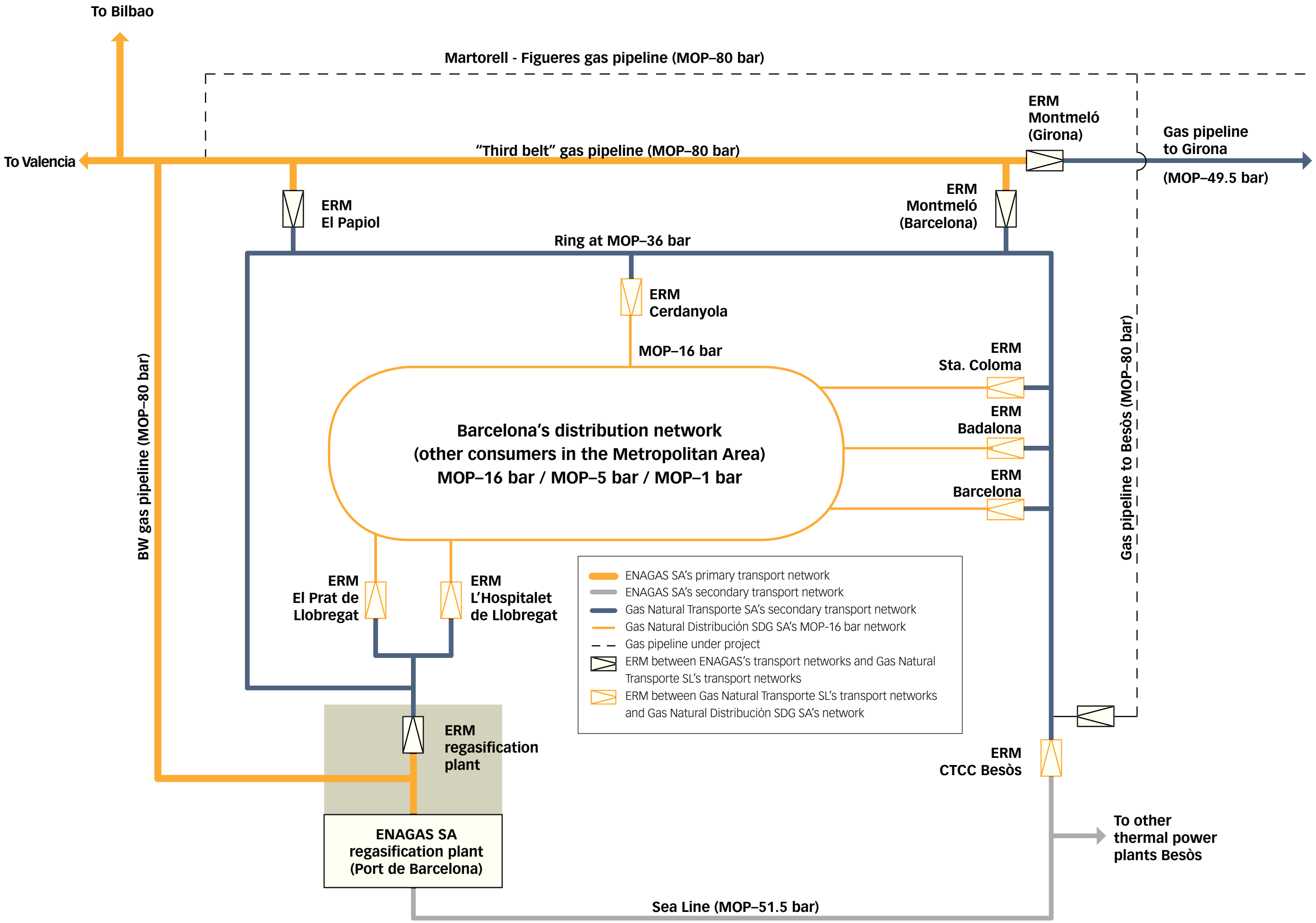
The distribution network in Barcelona is supplied by the transport network via 6 RMS located in 3 strategic areas (Zona Besòs: 3 MRS for connection from the east; Zona Llobregat: 2 MRS for connection from the southwest; Interior Area: 1 MRS for connection from the north-northeast). Future transport gas pipelines are planned for Martorell-Figueres and Besòs). In addition to the MRS and distribution and transport pipelines, the gas system in Barcelona has an Enagas regasification plant in the Port of Barcelona which receives liquefied natural gas from methane tankers, stores it and releases it into the transport network.

The current has network supplies in virtually all the inhabited areas except the new urban areas, where a higher degree of development is expected and in the new rollout areas where the extension of the network is at higher pressures.

In addition to these developments, where growth in domestic demand is expected, there are the new major consumers in the industrial sector (energy) concentrated mainly in:

- Combined-cycle thermal plants: Besòs 5, two 400 MW (commissioned in 2010).
- Combined-cycle thermal plants: Port of Barcelona, 1 and 2, 400 MW each one (commissioned in 2010).
- District heating & cooling in 22@ (planned to come into operation by the year 2011).
- Zona Franca-Gran Via Hospitalet energy plant, with a possible enlargement as a district heating & cooling plant (scheduled to come into operation by the year 2011).

FIGURE 104 | CONNECTION SCHEME BETWEEN THE TRANSPORT NETWORK AND DISTRIBUTION NETWORK IN BARCELONA



Source: Report on quality of gas supply services in Barcelona (QSSGB)

Planned infrastructures

Construction of two gas pipelines is planned for the area surrounding Barcelona - the future Martorell-Figueres pipeline, and the future pipeline in the Besòs, which will connect the former with the combined-cycle thermal plant in Besòs. Although this infrastructure does not directly affect natural gas supplies in Barcelona (as no connection is planned with the distribution network), a possible connection may be built in future.

The Planning of the electricity and gas sectors in 2008-2016. Development of the transport networks, approved by the Council of Ministers, does not provide for any new specific transport infrastructure to the gas pipelines which supply Barcelona and the metropolitan area. In view of this, taking into account the two planned pipelines, the transport network is sized to meet the foreseeable demand in 2008-2016.

This planning, however, does include enlarging the gas storage capacity in the Port of Barcelona, which is currently 540.000 m^3. Two more are planned for 2010-2011 (the 7th and 8th of the Barcelona plant), with a unit capacity of 150,000 m^3 together with the withdrawal from service of the three oldest and smallest tanks (two of 40,000 m^3 and one 80,000 m^3).

We should also underline how the investments made over recent years, the expanded capacity of the infrastructures up to a total of 250,000 m^3 (maximum moorage capacity of methane tankers), and the increase in the emission capacity of the regasification plant to 1,650,000 Nm^3/h in 2006, increased over the past three years to 1,950,000 Nm^3/h.

The measures to improve the capacity of the regasification plant in the Port of Barcelona were coming to an end in 2010 and the needs for 2008-2016 have been covered. For this reason no great modification is expected in the planning of the natural gas network for 2012-2020 which Enagas is starting to define

ENERGY SERVICE QUALITY

In order to monitor the quality parameters of the natural gas network, a series of changes is to be carried out over the coming years because, although Barcelona Council receives data on the quality of the electricity and natural gas supply, these are specific and fragmented.

It would therefore be necessary to ensure proper planning and management of the infrastructures, together with the commercial quality and information for users. In this respect, Barcelona City Council is working on a new agreement with the energy companies as a result of the meetings of the Urban Services Infrastructure Group (with the participation of the Council, the energy companies and several experts) to adopt agreements for the future development and improvement of the city's energy infrastructure.

When monitoring the quality of the energy service it would also be necessary to factor in the parameters described above and monitor these indices in a centralised manner. It would be convenient to apply new information systems and mechanisms in addition to updating the communication protocols. It is only in this way that an overview of the service quality in the city can be obtained so as to react swiftly when incidents occur or for preventive reaction situations.

Thus, the PECQ incorporates the following proposals (described in greater detail in the projects chapter of this Plan):

- Information system on the network and quality of the energy services.
- Support mechanism for decision-making on electricity infrastructure planning.
- Updating of the incident reporting protocol for the electricity and gas supplies

2.6 - Greenhouse gas emissions

2.6.1 - THE VOLUME AND SOURCES OF THE EMISSIONS

[24]Greenhouse gas emissions (GHG)23 in Barcelona in 2008 totalled 4,053,765.5 t - considering the electricity mix of Catalonia, a value which produces a ratio of 2.51 t/inhab/year. [25]The average annual increase rate between 1999 and 2008 was 1.72%, as in 1999 4,737,299.9 t were emitted, with a ratio of 3.15 t/inhab/year24.

It should be borne in mind that not all the reduction of emissions during these years was the result of efficiency improvements or a reduction in energy consumption (as occurred with natural gas consumption) but also of the changes introduced in the methodology applied in the Barcelona Energy Improvement Plan.

Thus, when drawing up the PECQ, the methodology used to calculate the GHG of Barcelona Port and Airport has been improved compared to that used in the PMEB; the emissions caused by the vehicle population of the city have been updated (as the previous inventories of emissions were based on the registered population, significantly older and therefore the source of more pollutants than that in circulation); and the emission factors of waste treatment have been updated, adapting them to European methodologies, which has meant that the GHG emissions are lower than with the previous procedure.

80.1% of GHG emissions (3,247,101.3 t/year) were the result of energy consumption in the city, while the remaining 19.9% were related to the treatment of municipal waste (8.1%) and port and airport activity (11.8%). Energy consumption is therefore the main cause of GHG emissions in the city, and shared almost equally between natural gas consumption (26.8% of the total), electricity consumption (26.7%) and automotive fuel (25.3%), while the remaining 1.3% is attributable to the consumption of liquefied petroleum gases (LPG).

By energy-consuming sectors, transport - including electricity and natural gas – is the chief emitter of GHG (26.2%), followed by the residential/housing sector (20.6%) and the commercial and services sector (19.4%). Industry is responsible for 13.5% of the remaining emissions, together with 0.5% attributable to other sectors (primary, energy, construction and public works).

As regards GHG emissions associated with the treatment of municipal waste, 0.6% (23,450 t) were produced in the energy-to-waste recovery plant in Sant Adrià, 5.2% (212,420 t) to the controlled waste landfill and 2.3% (91,710 t) to the combined treatment of municipal waste (Eco park plus incineration, Eco park plus tip, etc.).

24. Greenhouse gases [GHG] chiefly include carbon dioxide [CO_2], methane [CH_4], and nitrous oxide [N_2O].There are also other fluorinated gases produced by industry, but they are not directly related to energy consumption. CO_{2eq} or GWP (Global Warming Potential) is a measurement which uses the capacity of each substance to contribute to global warming in a single equivalent figure referenced for this purpose as regards CO_2 [$CO_{2eq} = GHG = CO_2 + 25CH_4 + 298N_2O$].

25. Due to variations in the calculation and updating method of the emission factors (applied both to calculations and historic data), the data published in the PMEB differ slightly from those mentioned here.

CALCULATION METHODOLOGY

While the emissions of the commercial and services sector, residential and industrial sectors are obtained from the billing details, the transport sectors, solid urban waste treatment, Port and Airport require an indirect or specific methodology.

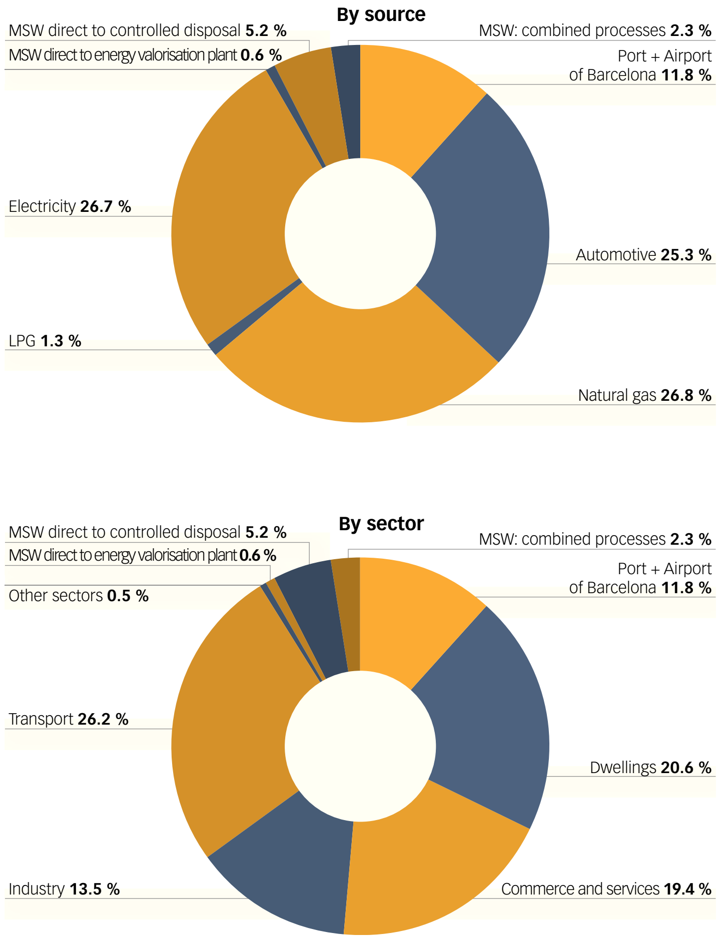
The **Port**: given that its activity takes place within the territory of the city, Barcelona assumes the total emissions calculated even though it serves other areas. The chief source of these emissions are goods and passenger transport vessels, tugs and ancillary systems and the circulation of vehicles - lorries and cars – within the Port area (this traffic is not included in the city road traffic figures). These emissions include vessels temporarily anchored outside the port awaiting entry, approach and stay with the engines running.

The **Airport**: Territorially located in the municipality of Prat de Llobregat, Barcelona Airport is of vital importance for the city's activity. According to a study commissioned as part of the PECQ, 48.1% of the economic activity generated by the Airport affects Barcelona, and accounts for 10.7% of the city's GDP. Thus, it was decided that Barcelona should bear 48% of the emissions associated with the Airport, which include handling and the Landing & Take-off cycle (LTO) of the planes.

Transport: public transport related emissions are readily ascertainable via the energy consumption monitored by the utility companies. On the other hand, road traffic emissions require a specific approach which is explained in Block 2 of this document.

Municipal Solid Waste treatment (MSW): waste treatment plants handle refuse from different municipalities. In order to assume emissions, those associated with the different plants in operation are weighted in accordance with the amount of material originating from the city of Barcelona. The emission factors have been updated with the latest figures published by the European Commission (proposed in the Waste Management Options and Climate Change report of the European Union).

FIGURE 105 | DISTRIBUTION OF GHG EMISSIONS IN BARCELONA (2008)



2.6.2 - EVOLUTION OF EMISSIONS

Evolution by sector and by energy source

GHG emissions in Barcelona between 1994 and 2005 saw sustained moderate growth (except for the years 2003 and 2004), up to a maximum of 4,917,700 t. From 2005 to 2008 there was a sharp drop down to 4,053,800 t (a figure below the levels of 1994).

Thus, the average annual rate of increase between 1999 and 2008 was -1.72%, a reduction caused by a drop in natural gas consumption, greater systems efficiency and improved waste treatment management. Despite this, a large part of this reduction in emissions must be attributed to changes in the methodology used, chief amongst which are the improved calculations of emissions from the Port and Airport of Barcelona, the more detailed study of the vehicle population and the updated emission factors for waste treatment.

The emissions which recorded the largest increase were those associated with electricity consumption - with an average annual rate of increase of 6.57%-, while those with the largest reduction were in municipal waste treatment, with a negative rate of 15.21% which includes the change in methodology mentioned in the preceding paragraph).

,

FIGURE 106 | EVOLUTION OF GHG EMISSIONS IN BARCELONA (1999-2008)

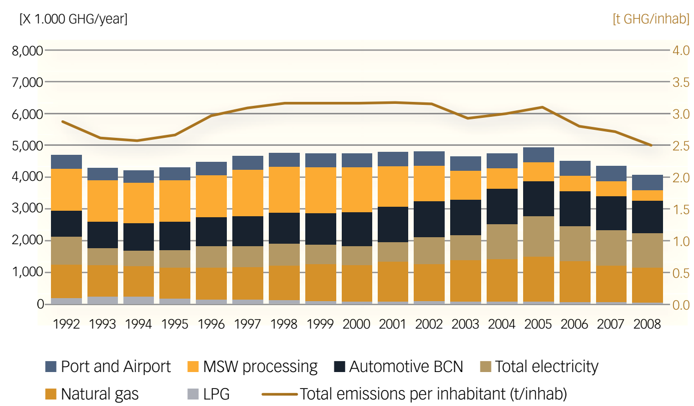


TABLE 30 | GHG EMISSIONS IN BARCELONA, BY SOURCE AND UNDER THE CATALAN ELECTRICITY MIX, IN TONNES (1999/2008)

GHG emissions in Barcelona, by source and under the Catalan electricity mix			
[t GHG x 1.000]	1999	2008	Average yearly increase rate 1999-2008
Liquefied petroleum gas (LPG)	97.15	53.15	-6.48%
Natural gas (not including vehicle NG)	1,152.14	1,086.78	-0.65%
Electricity	610.16	1,081.44	6.57%
Automotive (includes vehicle NG)	995.07	1,025.72	0.34%
MSW processing	1,446.40	327.58	-15.21%
Port and Airport	436.39	479.08	1.04%
Total [x1.000 Mt]	**4,737.30**	**4,053.77**	**-1.72%**
Total per inhabitant [Mt/inhab.]	**3.15**	**2.51**	**-2.50%**

By sectors, GHG emissions caused by the residential sector fell after 2006, following a sustained increase since 2001; the average annual rate of increase between 1999 and 2008 was 0.94%. The industrial and transport sectors (including electricity transport) underwent a similar evolution, with average increase rates of 0.49% and 0.40% respectively, between the years 1999 and 2008. On the other hand, the emissions produced by the commercial sector increased significantly, at a rate of 4.46%, although, like other sectors, it dropped over recent years, 2008 in particular.

This drop over recent years was basically in response to the reduction in energy consumption due to milder weather conditions. There was also a stabilisation of consumption in the transport sector due to road congestion in the city, the policies for the promotion of public transport over private transport and improved technology and efficiency of the vehicles.

[26]Total GHG emissions per inhabitant, considering the Catalan electricity mix, fell from 3.15 t/inhab in 199925 to 2.51 t/inhab in 2008, with a negative annual rate of increase of -2.50%. This figure is very low when compared with national European ratios or those of other cities.

As regards the GHG emissions factor per unit of energy consumed in the city - and using the Catalan electricity mix – it fell continuously between the years 1992 and 2008. The use of more efficient technologies in electricity production and final consumption appliances together with better waste treatment management were the chief causes.

FIGURE 107 | EVOLUTION OF GHG EMISSIONS IN BARCELONA BY SECTOR (1992-2008)

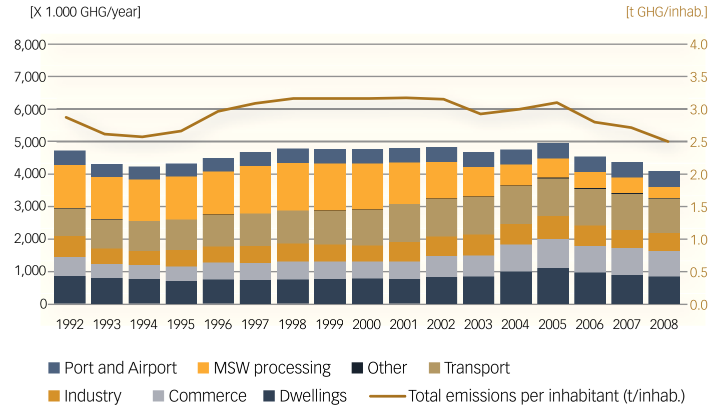
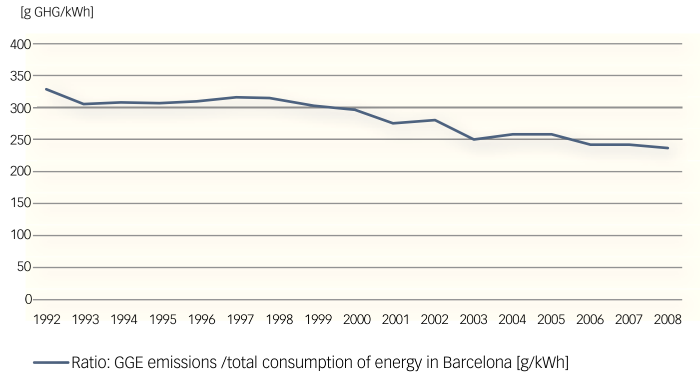


TABLE 31 | GHG EMISSIONS IN BARCELONA, BY SECTOR AND UNDER THE CATALAN ELECTRICITY MIX IN TONNES (1999/2008)

GHG emissions in Barcelona, by sector and under the Catalan electricity mix in tonnes			
[t GHG x 1.000]	1999	2008	Average yearly increase rate 1999-2008
Dwellings	766.22	833.43	0.94%
Commerce and services	530.18	785.47	4.46%
Industry	523.05	546.50	0.49%
Transport	1,024.62	1,061.89	0.40%
Other	10.45	19.82	7.37%
MSW processing	1,446.40	327.58	-15.21%
Port and Airport	436.39	479.08	1.04%
Total [x1.000 Mt]	**4,737.30**	**4,053.77**	**-1.72%**
Total per inhabitant [Mt/inhab.]	**3.15**	**2.51**	**-2.50%**

26. Due to variations in the calculation and updating method of the emission factors (applied both to calculations and historic data), the data published in the PMEB differ slightly from those mentioned here

FIGURE 108 | EVOLUTION OF THE ENERGY GHG EMISSION FACTOR IN BARCELONA (1992-2008)



Emissions in accordance with the electricity mix used

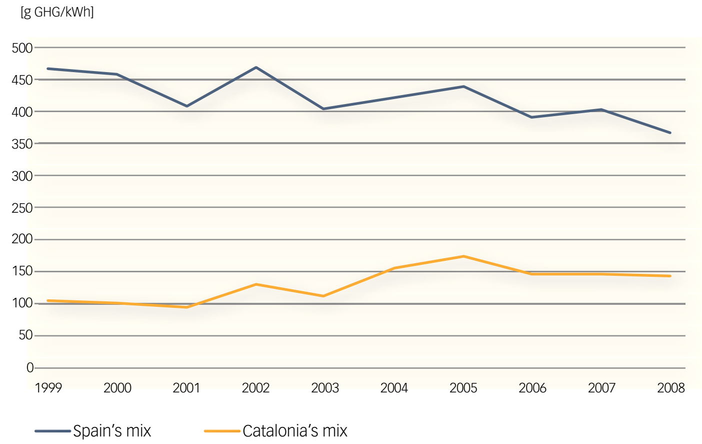
Electricity-related greenhouse gas emissions depend directly on the sources from which this energy has been produced, otherwise known as the electricity mix. This mix varies, however, depending on the territory under consideration -Catalonia or Spain- and therefore so does the calculation of the emissions (GHG emission factor per unit of electricity).

This emission factor, when calculated as the Catalan electricity mix, increased between 1999 and 2008, peaking in 2005 due to the greater use of combined-cycle power plants as water reserves for electricity production were insufficient due to the drought.

If, on the other hand, we consider the electricity mix of Spain, we find a reduction in the GHG emission factor per unit of electricity due to the change in the structure of Spanish power production over recent years: Greater utilisation of renewable energies and combined-cycle power plants, which reduced conventional thermo-electric production with coal and oil products, which are less efficient and more polluting.

The evaluation of total GHG emissions in Barcelona, depending on the use of either the Catalan or Spanish mix, shows a different distribution of each sector or source of the emissions. Thus, using the Spanish mix, the emissions resulting from electricity consumption increased in proportion, from 48.2% of the total (56% of emissions solely from energy consumption) exceeding those associated with natural gas consumption.

FIGURE 109 | EVOLUTION OF THE ENERGY GHG EMISSION FACTOR IN BARCELONA, ACCORDING TO THE CATALAN AND SPANISH MIXES (1999-2008)



An analysis by sector shows that the distribution also varies when using the Spanish mix, as the commercial and services sector (29.8% of the total, 34.7% of energy consumption) and the residential sector (23.4% of the total, 27.3% of energy consumption) became the largest GHG emitter, exceeding even the transport sector (19.5% of the total, 22.7% of energy consumption).

The evolution of GHG emissions also shows differences between the electricity mixes. When we apply the Spanish mix, emissions due to electricity consumption rose at an average annual rate of 0.16%, while the Catalan mix shows a rate of increase of up to 6.57%. The evolution of emissions due to the commercial and services sector also increases, at an average annual rate of 0.72% when using the Spanish mix and 4.46%, the Catalan mix.

TABLE 32 | GHG EMISSIONS IN BARCELONA, BY SECTOR UNDER THE CATALAN AND SPANISH ELECTRICITY MIXES, IN TONNES OF GHG (2008 AND AVERAGE ANNUAL RATES 1999/2008)

GHG emissions in Barcelona, by sector under the Catalan and Spanish electricity mixes, in tonnes of GHG				
	2008		Average yearly increase rate 1999-2008	
[t GHG x 1000]	CAT's elec. mix	SPAIN's elec. mix	CAT's elec. mix	SPAIN's elec. mix
Dwellings	833.43	1,343.80	0.94%	-0.35%
Commerce and services	785.47	1,710.33	4.46%	0.72%
Industry	546.50	704.49	0.49%	-1.80%
Transport	1,061.89	1,117.27	0.40%	0.18%
Other	19.82	50.60	7.37%	0.92%
MSW processing	327.58	327.58	-15.21%	-15.21%
Port and Airport	479.08	479.08	1.04%	1.04%
Total [x1.000 Mt]	**4,053.77**	**5,733.2**	**-1.72%**	**-1.96%**
Total per inhabitant [Mt/inhab.]	**2.51**	**3.55**	**-2.50%**	**-2.74%**

FIGURE 110 | DISTRIBUTION OF GHG EMISSIONS IN BARCELONA FROM WASTE TREATMENT PLANTS UNDER THE CATALAN ELECTRICITY MIX (2008)

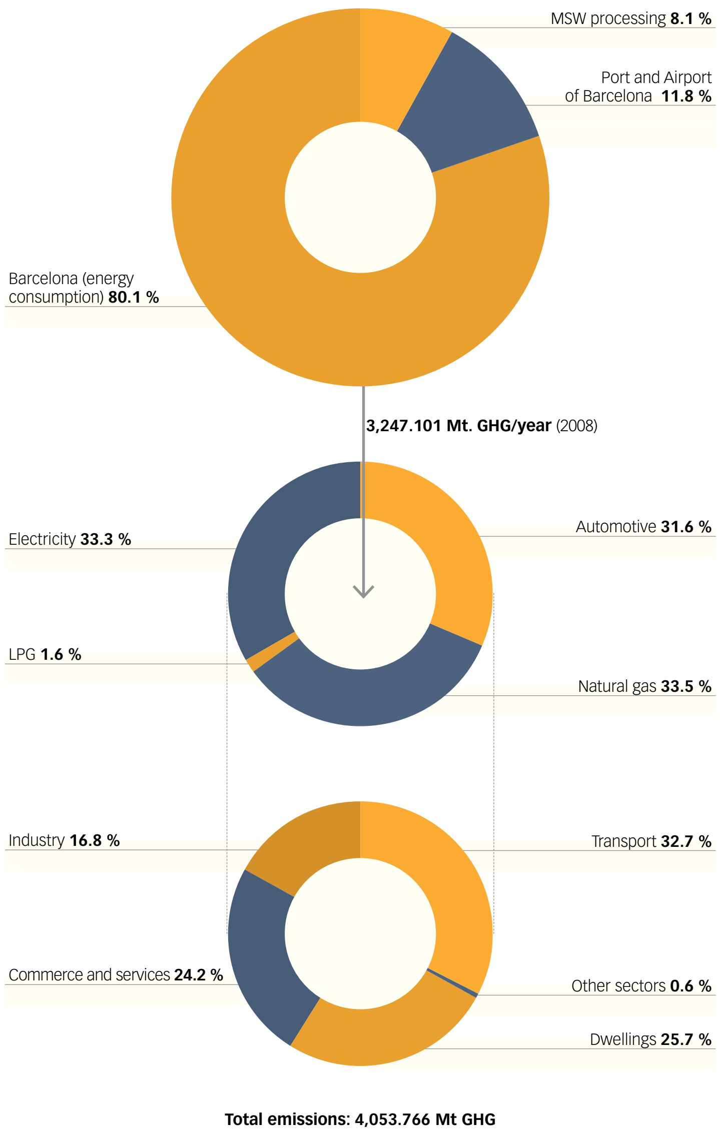
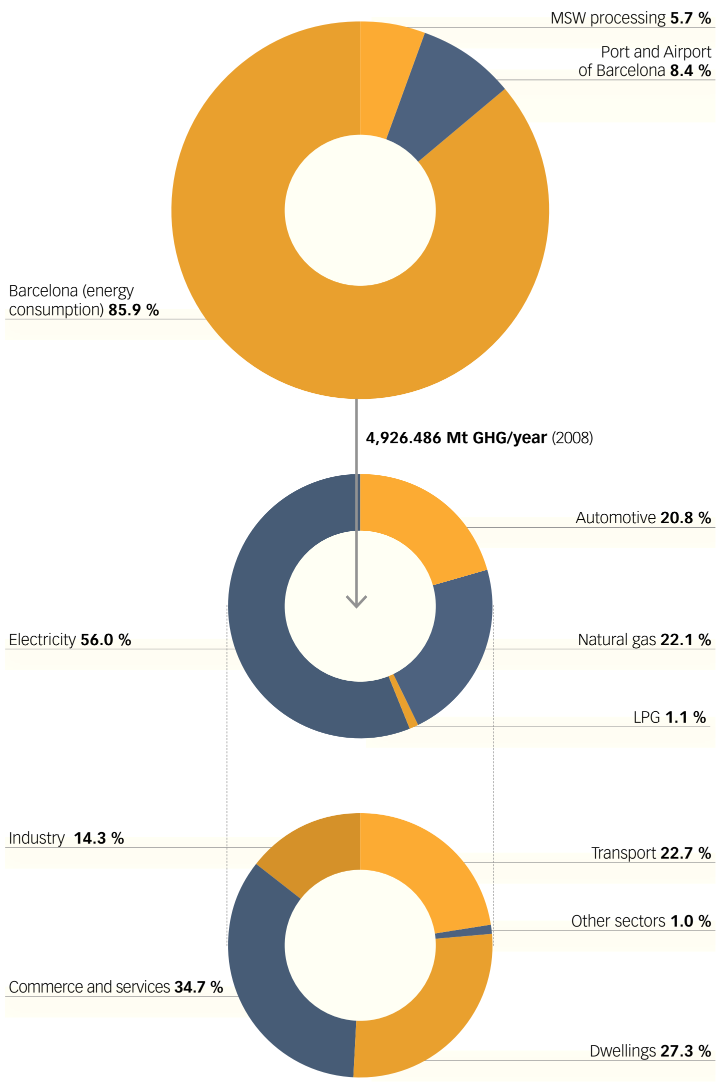
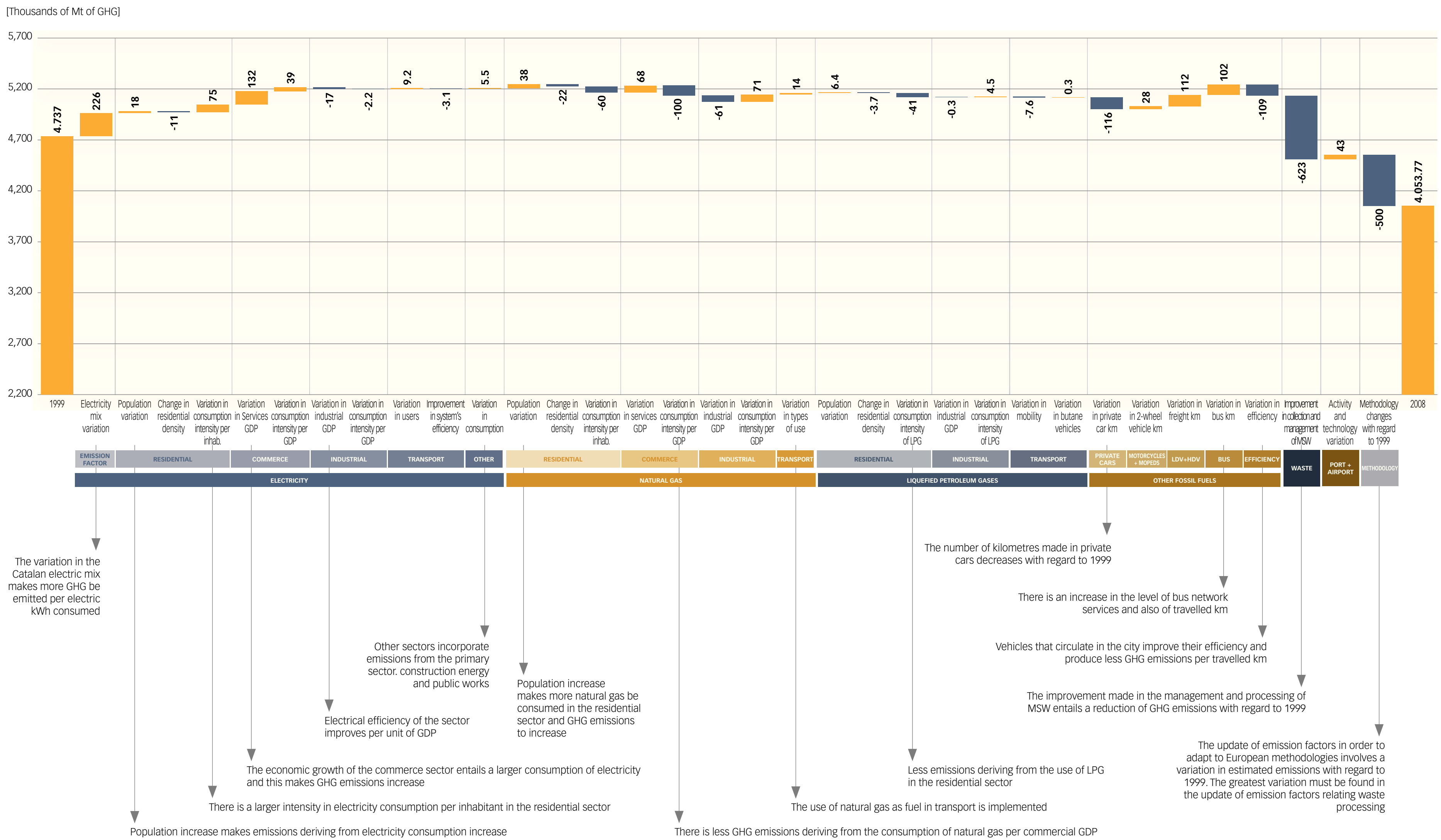


FIGURE 111 | DISTRIBUTION OF GHG EMISSIONS IN BARCELONA FROM WASTE TREATMENT PLANTS UNDER THE SPANISH ELECTRICITY MIX (2008)



Total emissions: 5,733.151 Mt GHG

FIGURE 112 | VARIATION OF GHG EMISSIONS IN BARCELONA (1999-2008)



2.7 - Air quality

2.7.1 - EMISSIONS INVENTORY

One of the challenges for this PECQ was to determine which human and/or natural activities cause the highest concentration levels of pollutants in the air, so as to focus its efforts on addressing and adopting the most suitable measures to reduce these levels.

To achieve this objective, an instrument has been used to model the dispersion of pollutants and diagnose the air quality in a given territory, taking into account variables such as energy efficiency, global reach emissions (GHG) and also more local emissions which directly affect the population's health.

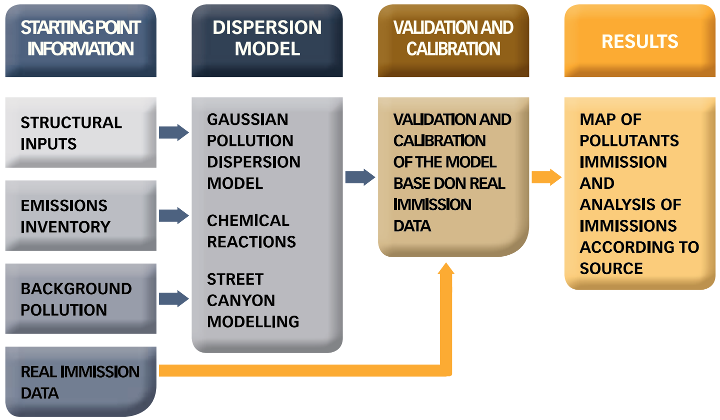
The methodology employed

The methodology employed to calculate the emissions is based on a pollutant dispersion model[27], used to model the chemical reactions between the various compounds and particles present in the atmosphere, together with the effects of solar radiation on them. This model also uses algorithms to evaluate wind speed at different altitudes, turbulence created by different land configurations and even air currents created at street level.

Hourly, weekly and monthly emission profiles can also be entered from the different sources of pollutants, so as to follow up the ongoing evolution of the emissions and their impact on the profiles. The model is also directly related with a Geographic Information System (GIS) and an emissions database for simpler quantification and geographic localisation of the sources of pollutants to a very accurate degree.

27. The Programme applied was the ADMS-Urban, a commercial programme used to evaluate the air quality in different cities worldwide, such as London, Manchester, Vienna and Beijing

FIGURE 113 | METHODOLOGICAL SCHEME USED TO MODEL AIR QUALITY IN THE PECQ



In the case of Barcelona, in order to model the levels of air quality it was necessary to perform a detailed inventory of the sources emitting pollutants over a larger area than the city itself (1,476 km^2), as atmospheric dynamics can carry compounds a great distance from the points of emission. Based on this inventory, and by using the integration of different biogeographical and urban variables (wind conditions, rainfall, height of the terrain, building configuration, concentration of sources, etc.) the levels of nitrogen oxide and solid particles were calculated (NO_2 and PM_{10}), as these are the pollutants which in Barcelona exceed the EU limits.

In order to achieve the greatest degree of detail - at street level – a mesh of 150,000 virtual points was created, distributed uniformly within the territory under consideration, in addition to 50,000 points using intelligent gridding, a method for refining the influence of traffic emissions on the surrounding area. In order to perform this modelling, the work of twelve processors operating uninterruptedly for 30 days was necessary. The year chosen to perform this modelling was 2008.

In order to calibrate and validate the model, the data were compared with the measurement stations of the Air Pollution Surveillance and Control Network (XVPCA), with virtual measurement points entered into the model at the same geo-referenced position. This analysis was able to adjust the modelling parameters to obtain emission results the closest possible to the real situation.

It should be remembered that reality is not a mathematical model and there are variables unrelated to parameterizable behaviour which distort the standard emissions profile; specific or uncontrolled situations such as traffic jams, fires, demolition of buildings, etc.

CHARACTERISTICS OF THE ANALYSIS MODEL

It is specifically designed to analyse the immission of pollutants in urban and metropolitan environment with street-level resolution.
It is based on a Gaussian pollution dispersion model.
It incorporates a meteorological pre-processing model.
It uses an hour-by-hour processing module of the flows and turbulence across the entire terrain. The module used is FLOWSTAR, a high resolution model designed for complex terrains.
It uses the OSPM model, specifically aimed at evaluating the street canyon effect which appears in the junctions between buildings, arising from the recirculation of the air and the turbulence created by vehicles and the buildings themselves.
It takes into consideration the chemical reactions between the various emissions in the atmosphere and those emitted by different sources. It also takes into account the photochemical reactions caused by solar radiation.
It has an intelligent system of virtual receivers, plus a regular mesh of points throughout the territory, so as to automatically assign measuring points around the sources of streets and roadways to increase the level of detail..

FIGURE 114 | PROFILE OF STANDARD EMISSIONS ON A WORKING DAY IN MARCH IN BARCELONA

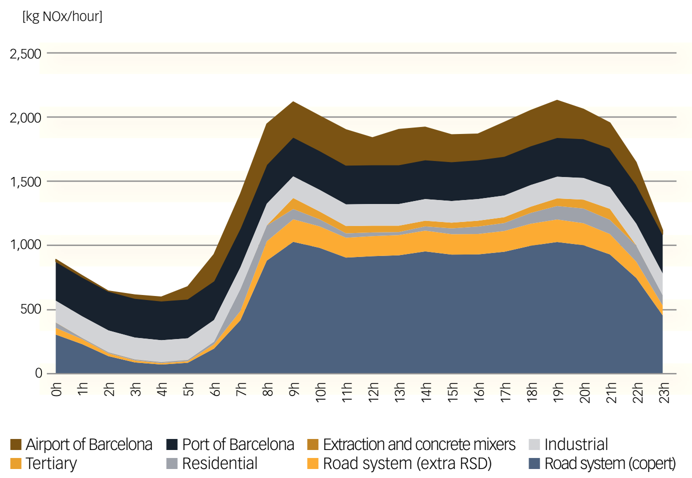
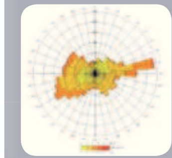


FIGURE 115 | STRUCTURAL INPUTS OF THE AIR QUALITY MODEL

Meteorological data



- In order to depict the scope under analysis, one of the key factors in order to analyse pollutants dispersion correctly is to obtain a series of meteorological data which are typical of the scope.
- The Meteorological Service of Catalonia has one of its centres in Barcelona's Raval neighbourhood, right in the city centre, which is highly representative of Barcelona's climate features. The hour-by-hour climate data used are those from 2008.

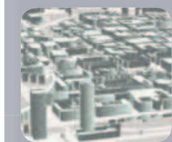
Cartography

- Orography and rough land. An hour-by-hour analysis is carried out on the air flows and turbulences originated in this area, deriving from the land's morphological characteristics.
- Contour lines have been extracted from the Catalan Institute of Cartography's topographic database. In addition, spot heights have been used to make up the group of points that are more representative from an orographic point of view, thus allowing the most uniform space coverage.
- The Soil Coverage Map of Catalonia has been used to determine the land's relief factor.

Road system infrastructures

- Ring-road system. The analysis is based on the traffic web prepared by Barcelona City Council Mobility Services, which incorporates the city road netting and other roads inside the area delimited by the ring-roads, in addition to those in the Besòs municipalities. There is a high level of detail, including crossroads and traffic intensity in every road stretch.
- Main and secondary out-of-city road system. The Department of the Environment and Housing provided data on the main road system close to Barcelona.
- Urban system in other towns. In order to round off the road system in municipalities neighbouring Barcelona information has been extracted from basic planimetry cartography prepared by the Catalan Institute of Cartography.
- TMB bus lines. Transports Metropolitans de Barcelona provided the routes of bus lines circulating in Barcelona and neighbouring towns.

Tri-dimensional building model



- A very important effect with regard to the dispersion of pollutants in urban areas is the organization of city streets due to turbulences created within. In order to calibrate such effect the OSPM (Operational Street Pollution Model) Danish model is used, which takes into account the actual turbulences created by traffic and those arising from neighbouring buildings' geometries.
- The Barcelona tri-dimensional model has been used to determine the heights of buildings from block to block.

NO_x and PM_{10} emission data

In 2008, 10,413 t of NO_x and 744 t of PM_{10} were emitted in the territory under study. The largest emitter was road transport, of both NO_x and PM_{10}.

The internal inventory of Barcelona for nitrogen oxides showed that traffic emissions were 4,849 t (4,157+692)[28] which account for almost half the total emissions within the city. The second source of emissions was the Port of Barcelona, with 3,078 t (1,566+1,512), part of which are caused by vessels (anchoring, approach and departure and tugs) and the rest from land operations (this includes vessels which are moored, the vehicles entering and leaving the port area and ancillary machinery). The third source of emissions were industrial activities, with 1,394 t of NO_x, which includes energy production activities, the chief industrial sources and other industries in the territory. The remaining volume of emissions originated from the residential and services sector with a total of 926 t.

As regards the emissions of particles in suspension, road transport within the city emitted 458 t from the following sources (according to the CORINAIR methodology): 91 t were direct emissions from exhaust pipes; 170 t were originated during combustion and the wear on brakes, tyres and asphalt; the remaining 197 t were obtained from the emissions measured in the streets of Barcelona, and revealed that vehicles in circulation had higher emissions than those stated in the European methodology (COPERT- CORINAIR).

The second source of particles were port activities, with 137 t (39 + 99), accounting for 18.5% of the total. The industrial and energy production sector as a whole emitted 133 t, and the residential and services sectors account for a total of 7 t. Emissions from extraction activities and major works were also considered and found to represent 8 t. It should be borne in mind that minor works also impact the total volume of emissions of particles in suspension, but their widely varying nature made it unfeasible to calculate in this inventory.

28. Road emissions are separated into two types: emissions according to COPERT (those calculated using the European methodology CORINAIR), and EXTRA RSD emissions (additional emissions which are detected in vehicle measurements in the city using the RSD system or Remote Sensing Device).

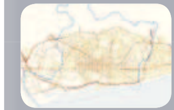
This volume of emissions refers to the inventory of those occurring within the municipal boundary of the city, yet for more refined and actual modelling of air quality, the territorial scope of the study must be extended as the different polluting compounds can travel great distances as a result of air currents. Thus, after analysing the results obtained, road circulation continues to be the chief emitter of both NO_x and PM_{10}.

If we compare the distribution of emissions by sectors in the city inventory with that of the broader territorial scope, there is a notable increase in the role of the industrial and energy generation sectors, the principal activities in the municipalities surrounding Barcelona. In the specific case of particles in suspension, emissions caused by extraction activities and major works represent 198 t of PM_{10}. Emissions at Prat Airport totalled at 1,608 t of NO_x and 21 t of PM_{10}, in 2008.

Lastly, we should add that part of the air pollution is caused by sources present in this territory and it either forms part of the usual concentration of these elements in the area or is due to the emissions of sources located at a great distance. This effect is called *"background pollution"*.

FIGURE 116 | SOURCES AND INVENTORY OF EMISSIONS IN BARCELONA

Road traffic emissions



- Traffic emissions per each street stretch in Barcelona (from one crossroads to the next) and neighbouring town roads.
- Monthly, daily and hourly profile based on traffic capacities.
- Description of vehicles circulating in the city as a whole. General picture of vehicles circulating in the city, focusing both on their characteristics and real emissions when they circulate. Please, see specific section for further information.
- Traffic emissions in the main roads outside Barcelona and urban roads in surrounding towns.
- TMB bus emissions with frequencies for each route and broken down per type of fuel.

Residential and tertiary sectors

- This is based on energy consumption data within the residential and tertiary sectors provided by ICAEN. These are distributed by energy uses and by territory according to building types as defined in the PMEB.
- NOx i PM_{10} direct emissions deriving from natural gas and LPG consumption are estimated according to consumption uses. The emission factors used are those set by the CORINAIR methodology.
- Monthly, daily and hourly profiles are being used.
- The same methodology is used for neighbouring towns estimating the land's distribution on the basis of land use according to the Map of Soil Coverage.

Energy generation and industrial sector

- The database used is owned by the Department of the Environment and Housing (DMAiH) and includes the mass emissions of the main NOx and PM_{10} emission focuses. This database incorporates the energy generation plants.
- In order to estimate the remaining emissions deriving from the industrial sector the consumptions of natural gas and LPG used are those provided by ICAEN and are distributed according to the geographical location of industries.
- In the case of neighbouring towns the same methodology is being used and emissions are distributed according to the use of soil.

Emissions deriving from the port's activity

- Emissions deriving from the Port's activity are taken into account on the basis of data provided by the Barcelona Port Authority.
- This includes emissions from vessels when approaching the port, while berthed and while anchored.
- It also includes emissions from auxiliary machinery and tugs.
- Monthly activity profiles are being used according to freight or passenger transportation.
- It includes emissions deriving from land transport within the port's area based on the number of vehicles and the survey on characterisation of vehicles in situ within the Port.

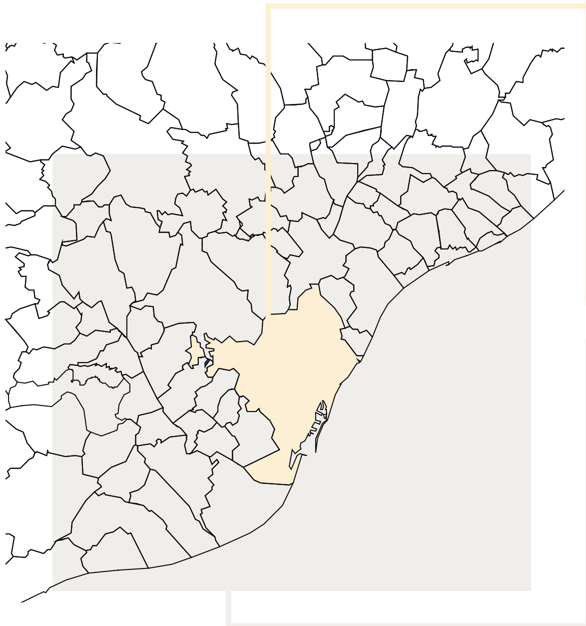
Airport emissions

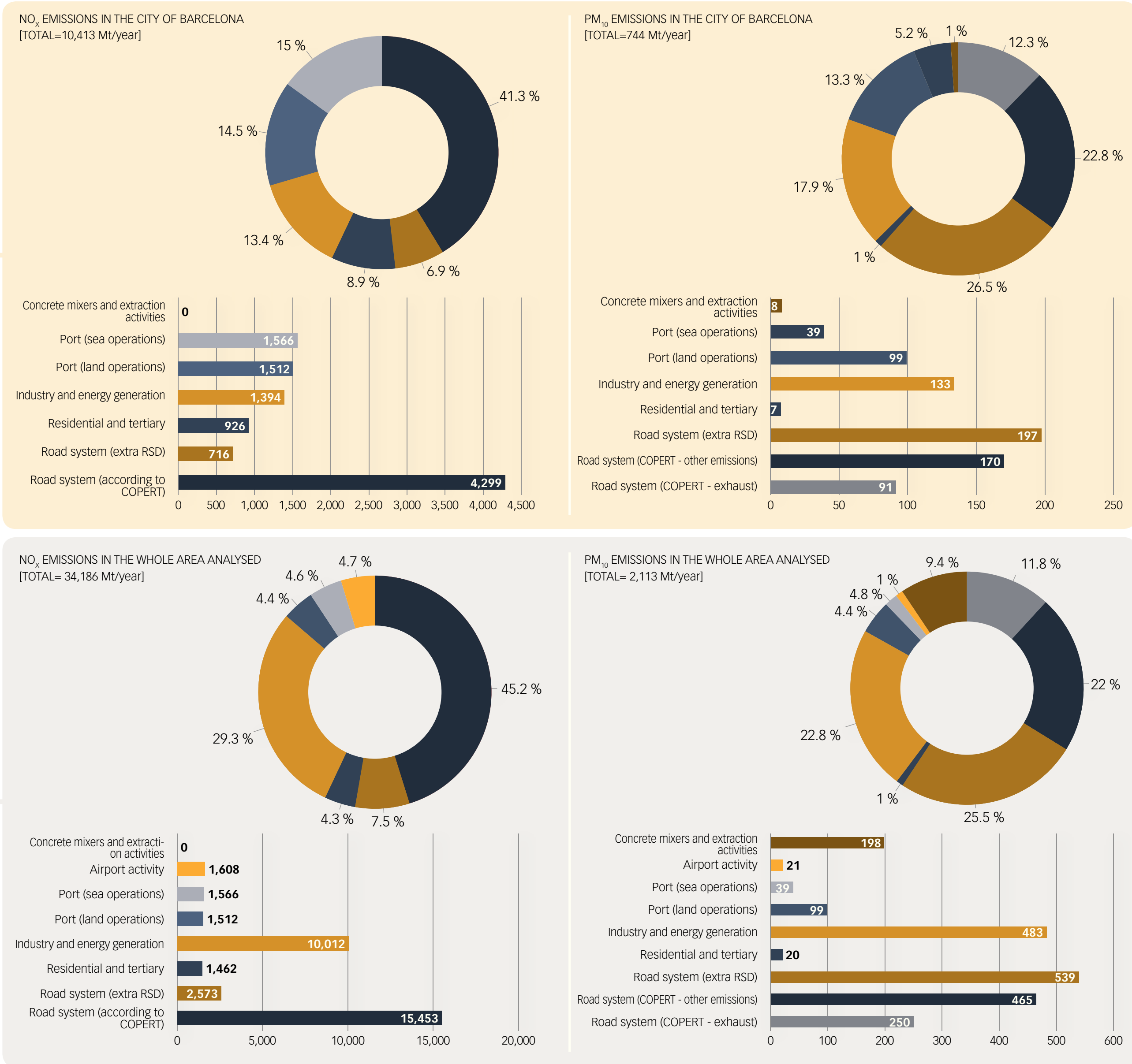
- NOx and PM_{10} emission data provided by AENA are being used.
- Direct emissions from aircrafts: these include the LTO cycle – landing, land movements and take off up to 3,000 feet.
- Auxiliary machinery and handling emissions.
- The trajectory of emissions according to flight operations in every runway is being considered bearing in mind monthly and hourly profiles of landings and take-offs.

Extraction activities and large concrete mixers

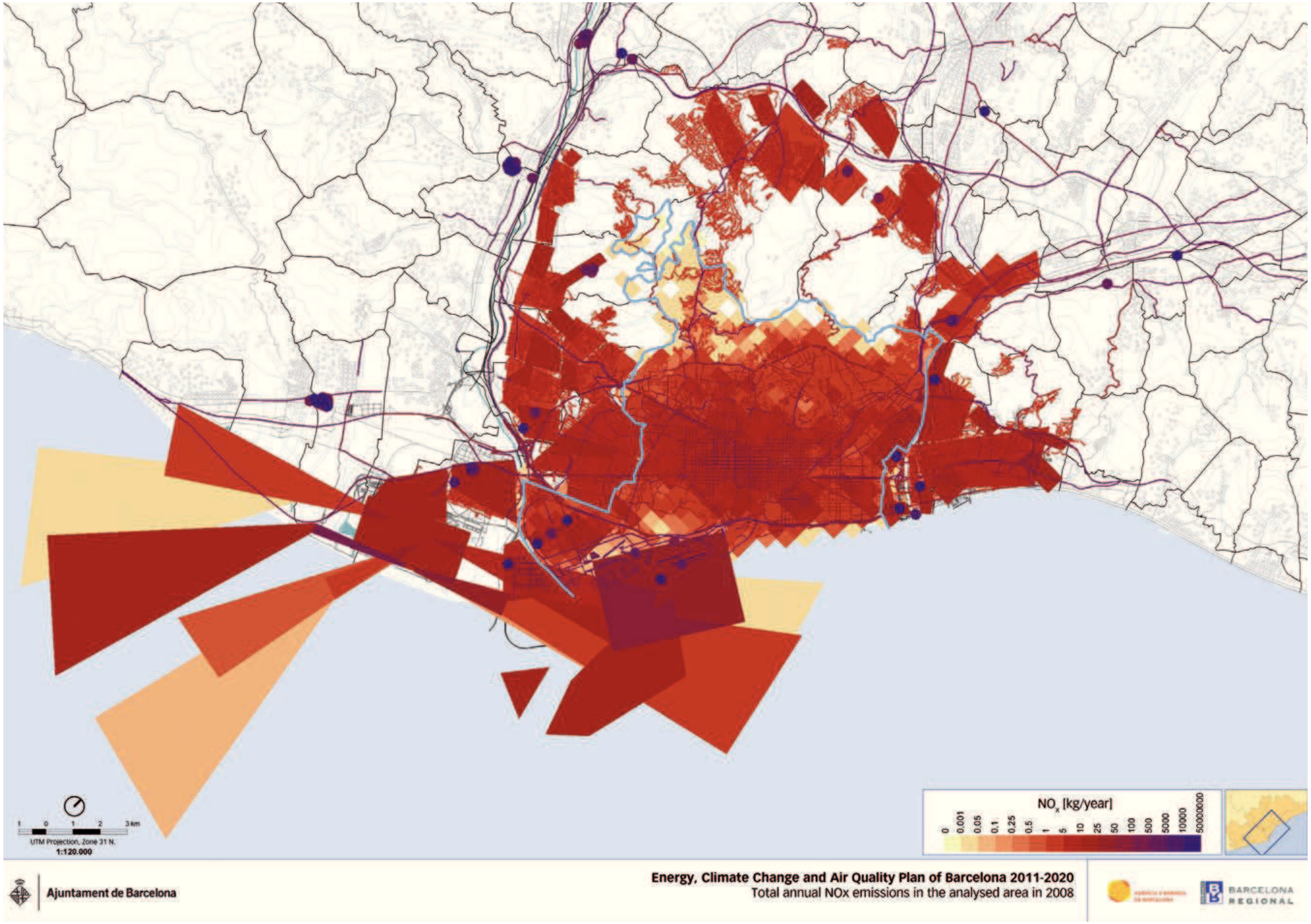
- The inventory of PM_{10} emissions deriving from extraction activities and from works with large mixers in the whole area under analysis, provided by the Department of the Environment and Housing.

FIGURE 117 | INVENTORY OF EMISSIONS IN BARCELONA CITY AND ACROSS THE ENTIRE SPHERE UNDER STUDY





Note:
"COPERT - EXHAUST" are exhaust emissions from the engine.
"COPERT - OTHER EMISSIONS" are non-exhaust emissions including emissions from vehicle brakes' wear. tyre wear by bearing and asphalt wear.
"EXTRA RSD" are emissions not included in the COPERT methodology detected in the measurements of vehicle emissions by means of the RSD (Remote Sensing Device) system.


1 0 1 2 3 km
UTM Projection, Zone 31 N.
1:120.000
NO_x [kg/year]
0 0.001 0.05 0.1 0.25 0.5 1 5 10 25 50 100 500 5000 10000 50000000
Ajuntament de Barcelona
Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Total annual NOx emissions in the analysed area in 2008
BARCELONA REGIONAL

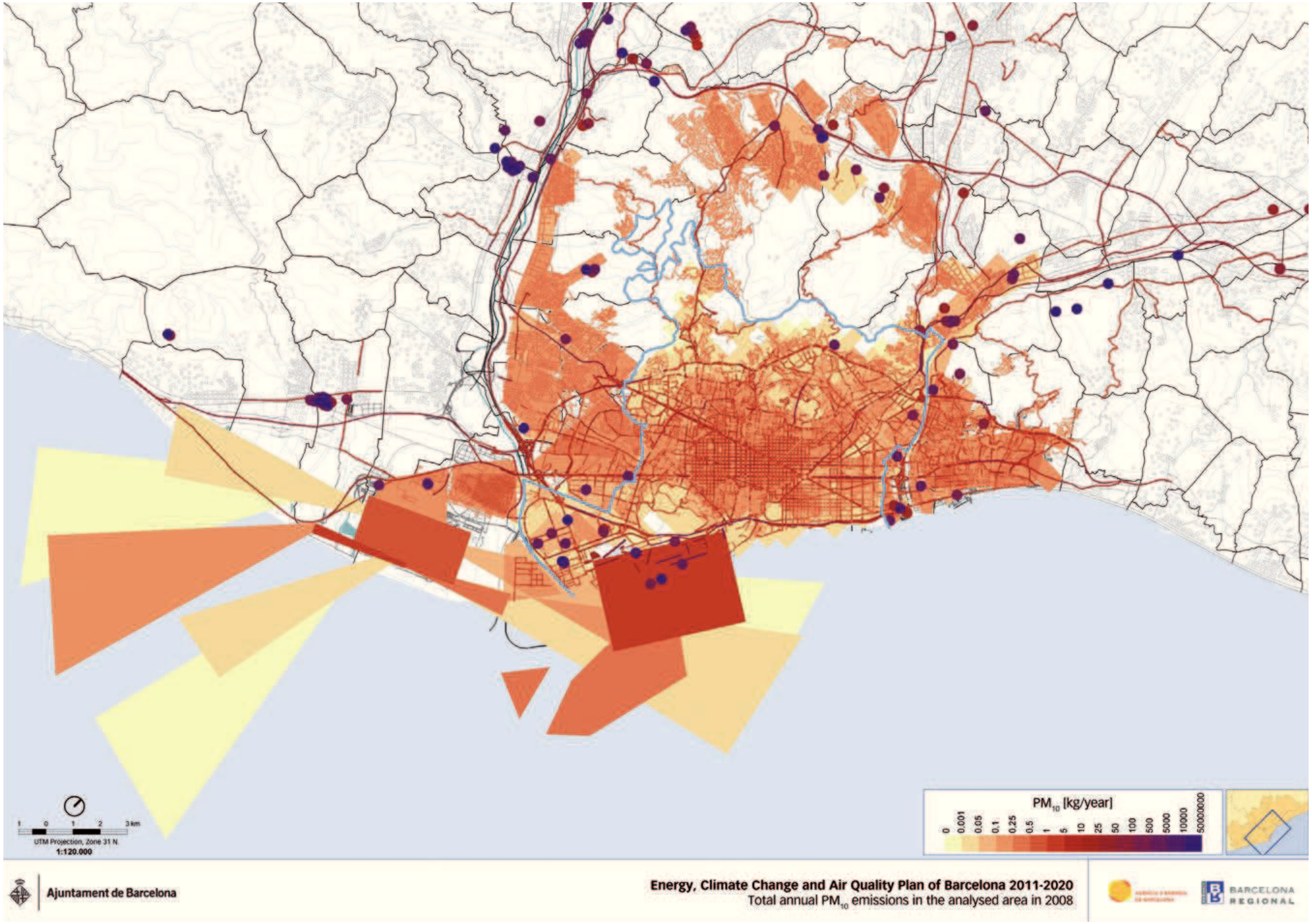
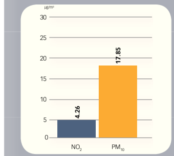

PM10 [kg/year]
0
0.001
0.05
0.1
0.25
0.5
1
5
10
25
50
100
500
5000
10000
50000000
1 0 1 2 3 km
UTM Projection, Zone 31 N.
1:120.000
Ajuntament de Barcelona
Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Total annual PM10 emissions in the analysed area in 2008
BARCELONA
REGIONAL

FIGURE 118 | **SOURCES AND INVENTORY OF EMISSIONS IN BARCELONA**

Data on levels of background pollution



- The data used was provided by AEMET's background pollution station in Cap de Creus in order to consider the levels of pollutants not directly linked to activities in the area.
- Hourly data on NO_2, NO, SO_2 and O_3, and daily data on PM_{10} are available.
- The annual average value of main pollutants are:
  NO_2 : 4,26 µg/m³ NO : 0,30 µg/m³ PM_{10} : 17,85 µg/m³
  SO_2 : 0,33 µg/m³ O_3 : 74,4 µg/m³

2.7.2 - IMMISSION DATA

The values detected

The pollutant dispersion modelling is carried out using the geo/referenced inventory of emissions and all the structural and boundary variables. In order to calibrate the model, the modelling parameters are adjusted to the real values recorded by the automatic and manual measuring points of the Air Pollution Surveillance and Prevention Network in Barcelona.

Calibrating the model entails adding the local background pollution: emission sources not calculated or underestimated, real background pollution, re-suspension of particles, specific episodes and/or system behaviour which differ from the daily, weekly or monthly profiles entered in the model. This local background pollution represents an average annual increase of 5 µg/m³ of NO_2 and 15 µg/m³ of PM_{10} in Barcelona.

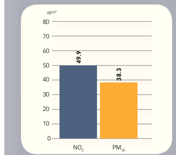
After performing the calibration, when the values obtained using the model are compared to the real levels of annual concentration, in the case of NO_2 the real average value of the city of Barcelona in 2008 was 49.9 µg/m³, while the model recorded a concentration of 449.5µg/m³. i.e., a 99.1% match with the real situation, with minor variations at certain measuring stations.

As regards PM_{10}, in 2008 the real average value was 38.3 µg/m³, while the model gave a concentration of 337.3µg/m³, slightly underestimating the total particles in suspension but achieving a strong similarity with the real figure of 97.4%.

We can therefore say that the pollutant dispersion model adapted to the conurbation of Barcelona offers a value strongly aligned with reality, making it possible to analyse in detail the factors and sources which most affect the concentration of NO_x and PM_{10}, and propose more effective policies and measures to improve air quality.

FIGURE 119 | DETAILS ON IMMISSION LEVELS IN BARCELONA AND ITS SURROUNDING AREA

Data on levels of immission in barcelona and its surrounding area



- Hourly and daily data on NO_2 immissions and particles in suspension in the city of Barcelona and its surrounding area.
- Manually and automatically-obtained data from the Air Pollution Surveillance and Control Network (XVPCA), to validate and calibrate the dispersion model.

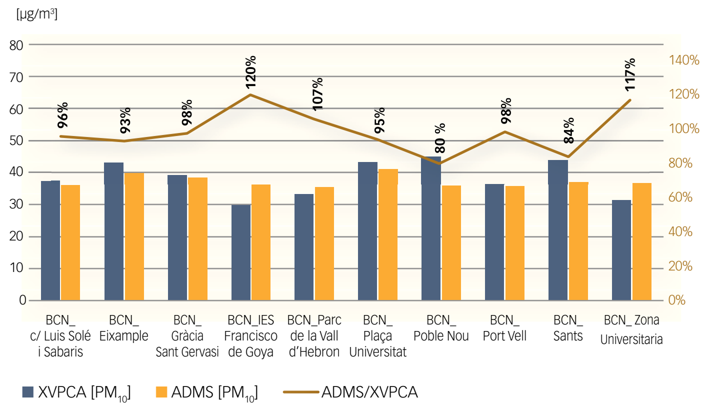
DEFINITION: EMISSIONS / IMMISSIONS

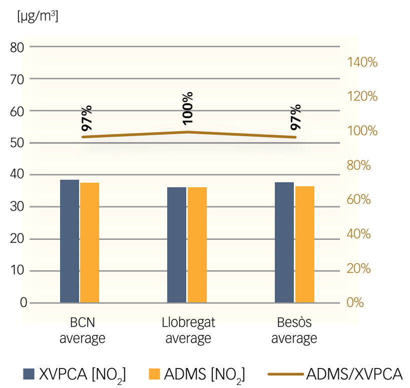
Emissions are the amount of pollution which a specific source emits into the atmosphere over a given period of time. Immissions, on the other hand, are the concentration of a pollutant in a given place. Immission levels or air quality are those which determine the effect of a given pollutant on health. Therefore, in order to reduce air pollution, it is necessary to control atmospheric emissions and monitor the presence of pollutants in the air at different reception points (immission levels).

FIGURE 120 | COMPARISON OF REAL IMMISSION VALUES OF NO_2 WITH THOSE MODELLED IN BARCELONA (2008

Source: XVPCA

FIGURE 121 | COMPARISON OF REAL IMMISSION VALUES OF PM_{10} WITH THOSE MODELLED IN BARCELONA (2008)





Source: XVPCA

CARTOGRAPHIC EXPRESSIONS OF RESULTS

After calibrating and validating the model with the data measured at the XVPCA immission stations, the map of air conditions in Barcelona is prepared. The pollutants regulated by Royal Decree 1073/2002 are NO_2 and PM10, which must not exceed a level of 40 µg/m³ on an annual average as from the year 2010. 55% of the territory (56 km2) exceeded 40 µg/m³ immissions of NO_2 in 2008. In the Eixample and neighbouring areas, the values totalled between 50 and 60 µg/m³. In areas near heavy traffic very high levels were also reached.

As regards the concentration of PM10, 17% of Barcelona exceeds the annual limit of 40 µg/m³, although a large part of the city was close to these levels. Specifically, and in accordance with the model, approximately two thirds of the territory was in the range of 35-40 µg/m³ and therefore very close to exceeding the annual limits. According to the dispersion maps, the annual average of 40 µg/m³ was exceeded in the Eixample and the surrounding areas of heavy traffic streets.

In order to detect the differences in air quality at different points in the city, an analysis of the immissions was carried out at three longitudinal sections of the map of the annual average concentration of NO_2. This analysis revealed the major impact of traffic on the concentration of pollutants, especially in the roads with the heaviest traffic and junctions. Immission peaks coincided with the junctions, but just a few metres from the traffic they fell off sharply. This phenomenon causes pollutant concentrations in buildings and parks to reach the levels of the city as a whole.

We should also underline the increased concentration in the city centre and especially the Eixample network, where the average immission was higher. On the other hand, in areas with large green spaces such as the Ciutadella Park or Montjuïc mountain, there was a clear reduction in the concentration given the non-existence of major sources of emissions.

FIGURE 122 | DISTRIBUTION OF THE SURFACE AREA OF BARCELONA IN ACCORDANCE WITH NO_2 IMMISSIONS(2008)

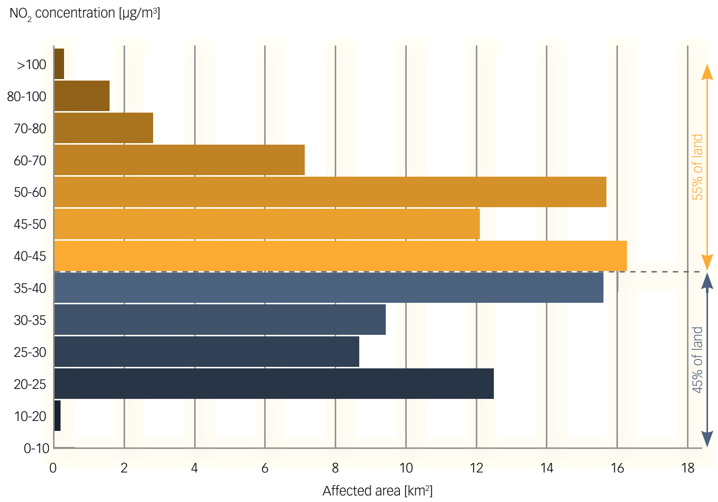
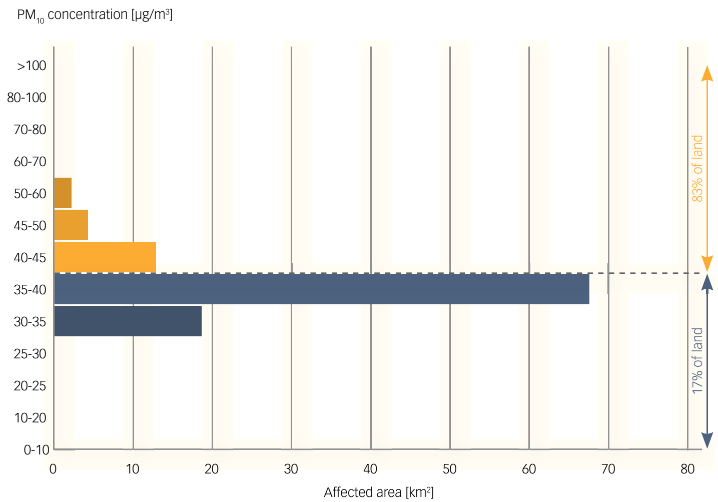
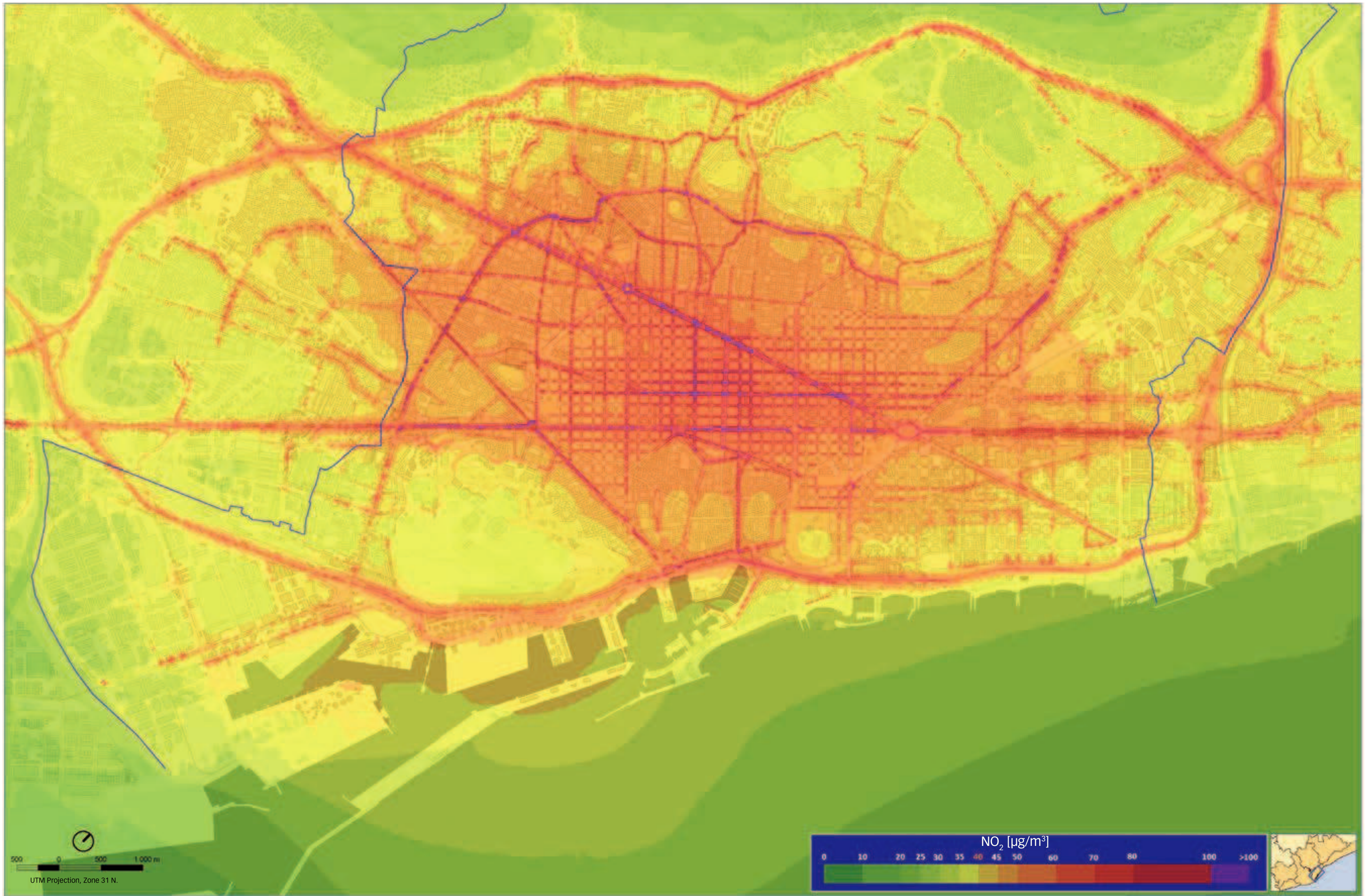


FIGURE 123 | DISTRIBUTION OF THE SURFACE AREA OF BARCELONA IN ACCORDANCE WITH PM_{10} IMMISSIONS (2008)



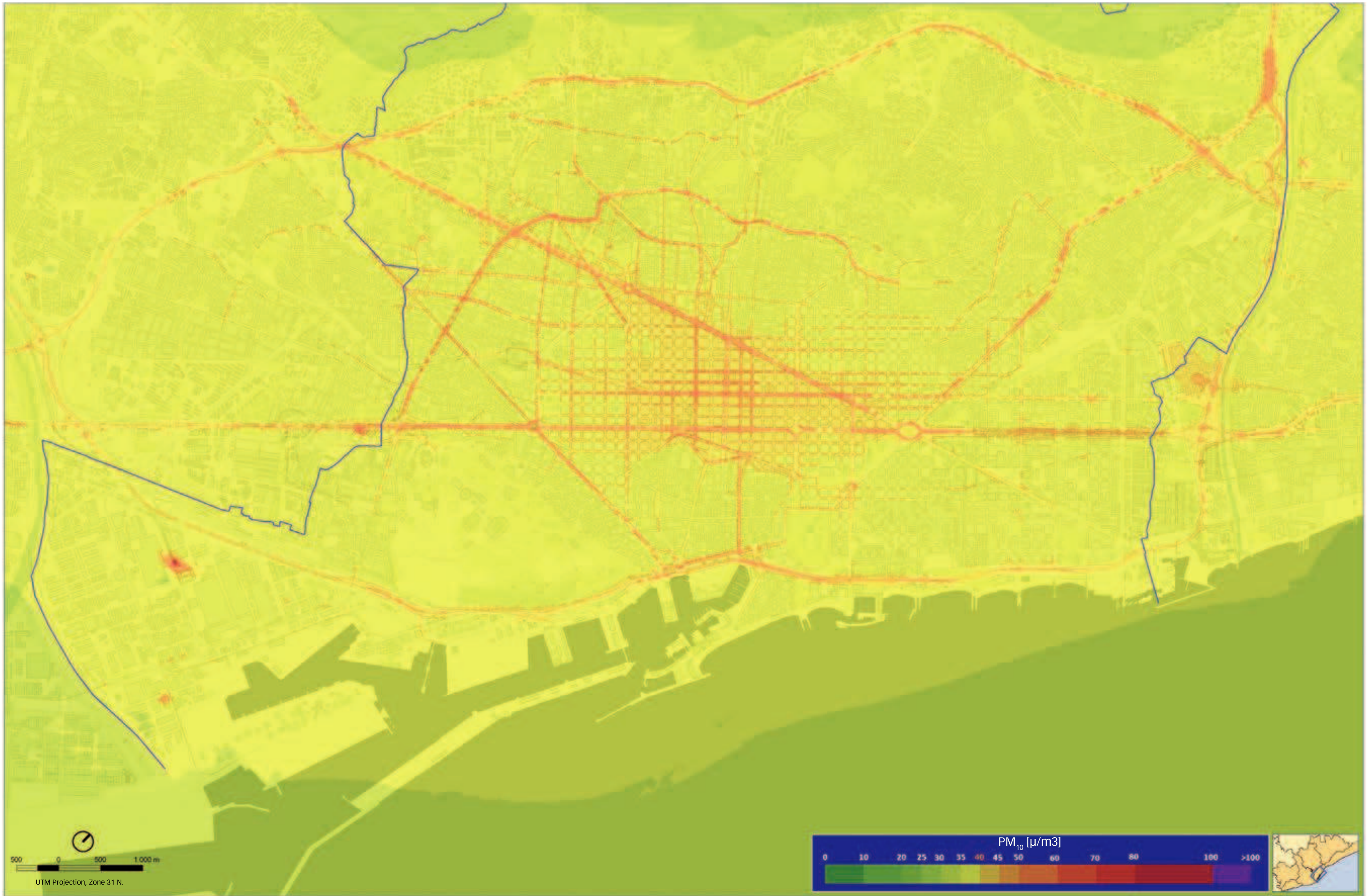


Ajuntament de Barcelona

Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020

Annual average immission of NO_2 in Barcelona in 2008

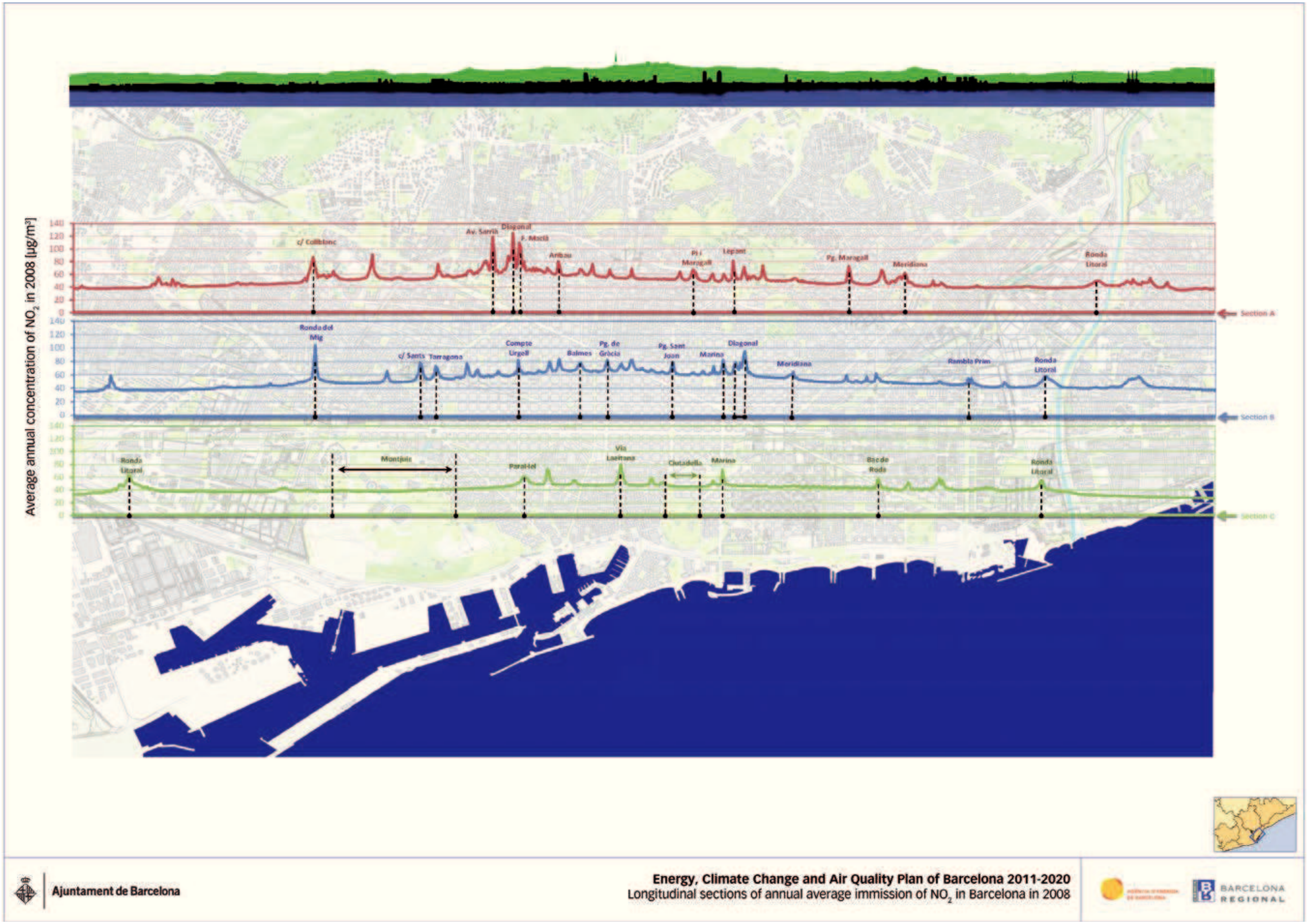
BARCELONA REGIONAL



Ajuntament de Barcelona

Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Annual average immission of PM_{10} in Barcelona in 2008

BARCELONA REGIONAL


Average annual concentration of NO_2 in 2008 [µg/m³]
Ajuntament de Barcelona
Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Longitudinal sections of annual average immission of NO_2 in Barcelona in 2008
BARCELONA REGIONAL

Immissions by source of emission

As not all the pollutant sources affect air quality to the same extent, it is necessary to ascertain in detail the origin of the pollution.

In Barcelona in 2008, approximately 65.6% of the concentration of NO_2 in the air (56%+9.6%) was caused by road transport, 8.68% by the residential and commercial sectors and 4.8% by the industrial and energy production sectors, 2.1% by port activity and 0.1% by the Airport. There was also a major affect by the regional background pollution, 10.1%, and local background pollution, 8.6%.

In the case of PM_{10}, the strong influence of regional background pollution was detected, which accounted for almost half the concentration (47.9%; 17 µg/m^3 according to the background station at Cap de Creus). Local background pollution accounted for 40.2% of total immissions. Of the pollution which is directly attributable to the city's activity, 11.0% was caused by traffic (6.3%+4.7%)[29], 0.3% by industrial and energy production activities, 0.3% from port activities and 0.2% by major works and extraction activities. The influence of the Airport was almost indiscernible.

The main conclusions of this analysis of emissions sources for the year 2008 are that:

- Road traffic is the human activity with the greatest influence on air quality in Barcelona, both for NO_2 and PM_{10}.
- NO_2 immissions are also strongly influenced by emissions from the residential, commercial and industrial sectors.
- In the case of PM_{10}, immissions, despite being strongly influenced by sources not directly attributable to the city, the industrial sector, port activity or works and extraction activities throughout the territory are a major cause of pollution.
- There is a noteworthy impact of background pollution, which in 2008 accounted for a large part of these immissions (8.6% in the case of NO_2 and 47.9% for PM_{10}), and which was caused by factors lying outside the territory.
- Local background pollution (especially in the case of particles in suspension) represents the immission due to emission sources, levels or profiles which are the most difficult to identify and parameterize (1.1% in the case of NO_2 and 40 2.% in the case of PM_{10}).

29. Road transport immissions are separated into two types: immissions from emissions according to COPERT (calculated according to the European methodology CORINAIR); and immissions from EXTRA RSD emissions (additional emissions detected in vehicle measurements using the RSD system or Remote Sensing Device).

FIGURE 124 | DISTRIBUTION OF THE ANNUAL AVERAGE OF NO_2, BY SECTOR (2008)

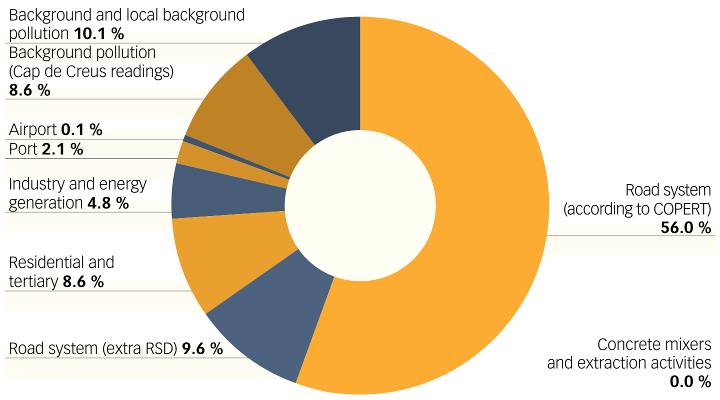
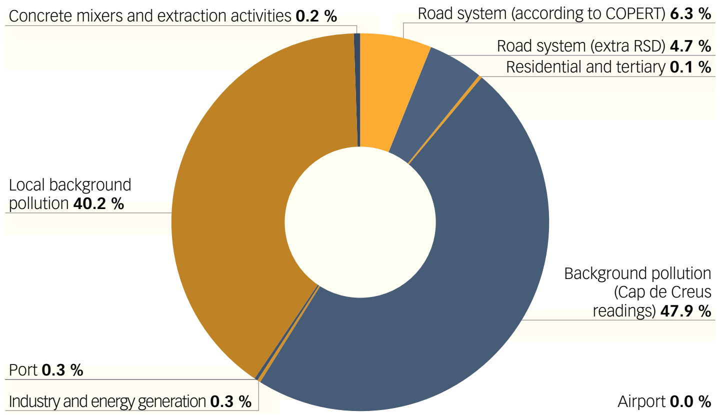
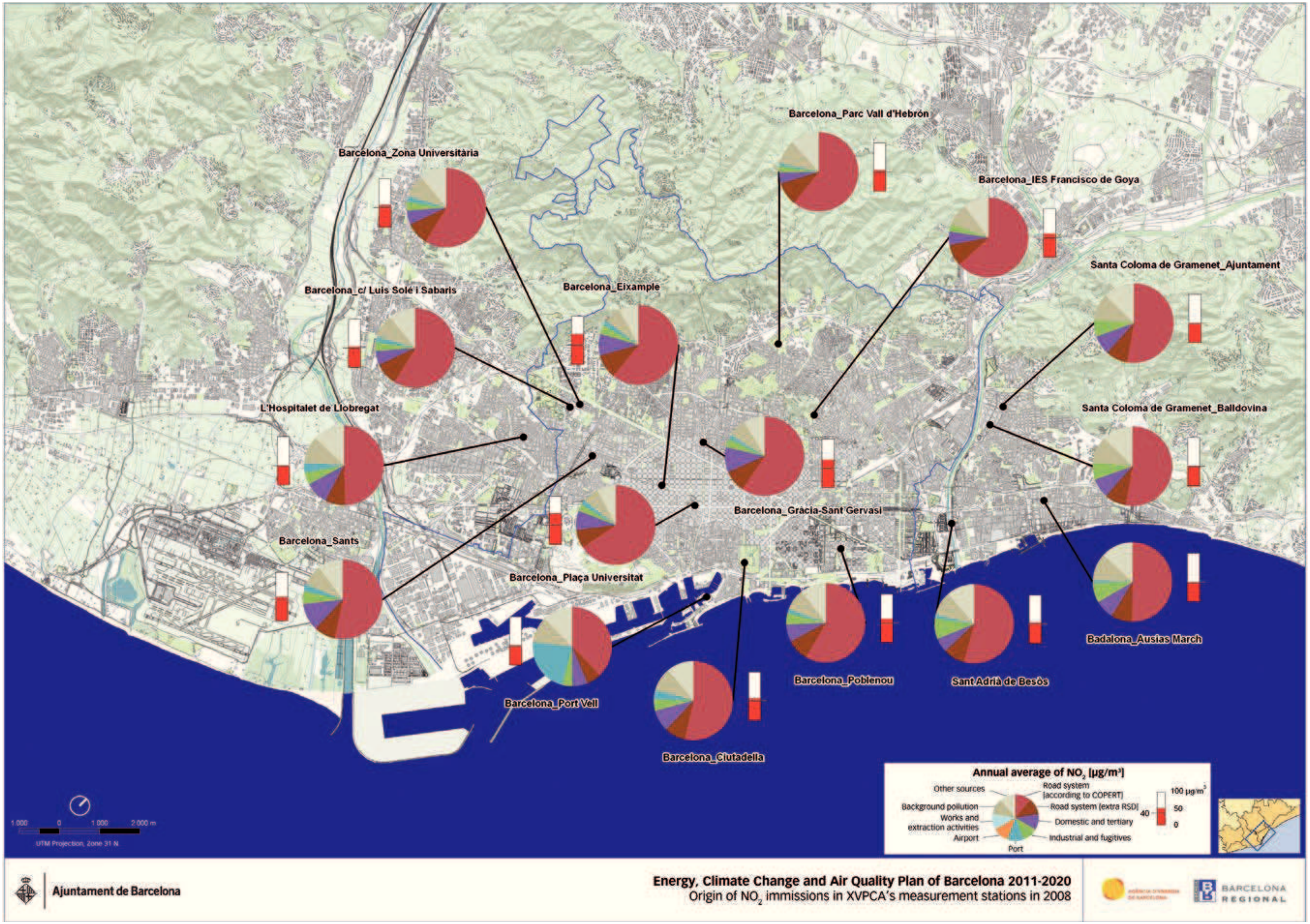
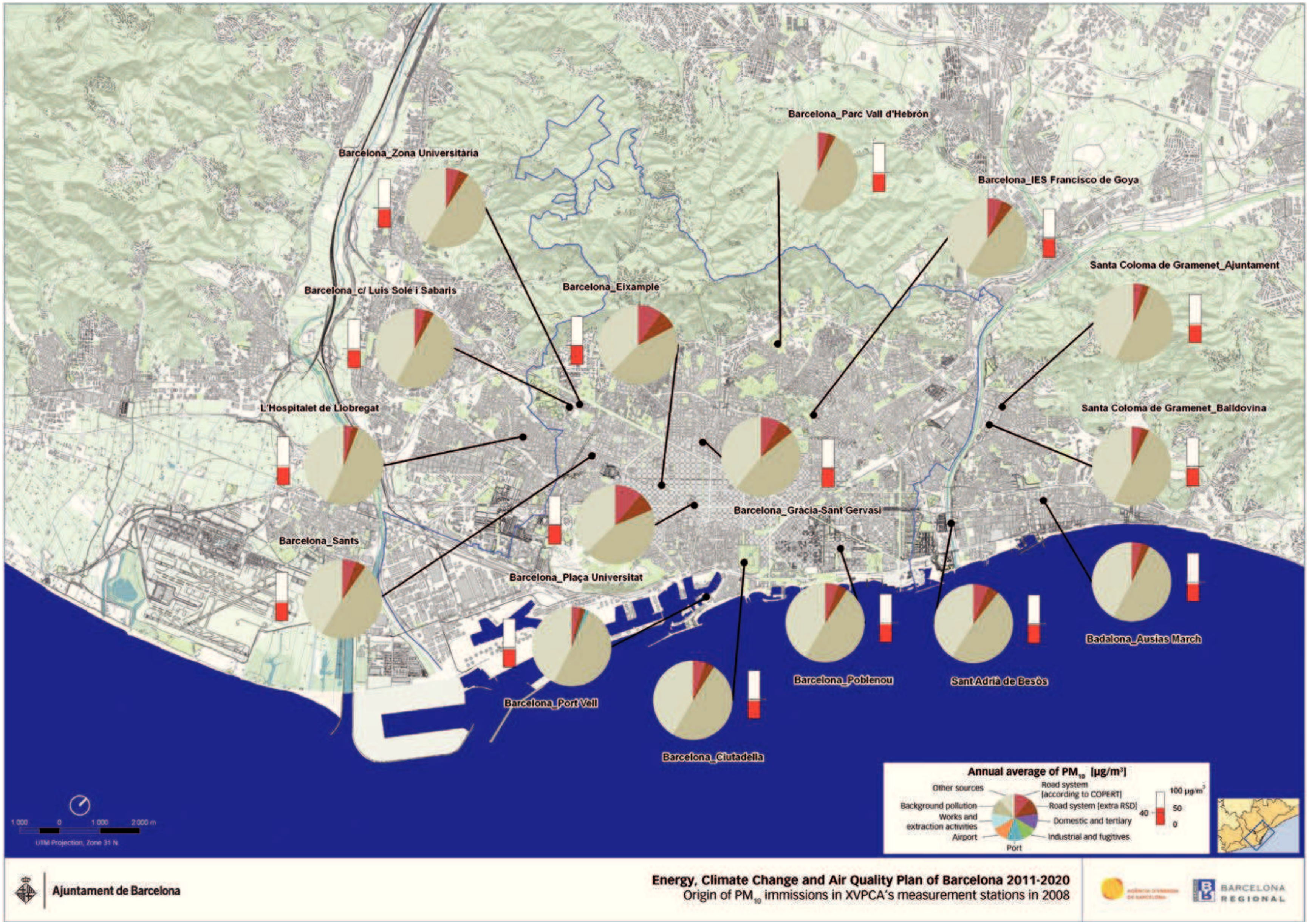


FIGURE 125 | DISTRIBUTION OF THE AVERAGE OF PM_{10}, BY SECTOR(2008)




Barcelona_Parc Vall d'Hebrón
Barcelona_Zona Universitària
Barcelona_IES Francisco de Goya
Santa Coloma de Gramenet_Ajuntament
Barcelona_c/ Luis Solé i Sabarís
Barcelona_Eixample
L'Hospitalet de Llobregat
Santa Coloma de Gramenet_Balldovina
Barcelona_Gràcia-Sant Gervasi
Barcelona_Sants
Barcelona_Plaça Universitat
Badalona_Ausias March
Barcelona_Poblenou
Sant Adrià de Besòs
Barcelona_Port Vell
Barcelona_Ciutadella
Annual average of NO_2 [µg/m³]
Other sources
Road system [according to COPERT]
Background pollution
Road system [extra RSD]
Works and extraction activities
Domestic and tertiary
Airport
Industrial and fugitives
Port
100 µg/m³
50
40
0
UTM Projection, Zone 31 N
Ajuntament de Barcelona
Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Origin of NO_2 immissions in XVPCA's measurement stations in 2008
BARCELONA REGIONAL


Barcelona_Parc Vall d'Hebrón
Barcelona_Zona Universitària
Barcelona_IES Francisco de Goya
Santa Coloma de Gramenet_Ajuntament
Barcelona_c/ Luis Solé i Sabarís
Barcelona_Eixample
L'Hospitalet de Llobregat
Santa Coloma de Gramenet_Balldovina
Barcelona_Gràcia-Sant Gervasi
Barcelona_Sants
Barcelona_Plaça Universitat
Badalona_Ausias March
Barcelona_Poblenou
Sant Adrià de Besòs
Barcelona_Port Vell
Barcelona_Ciutadella
Annual average of PM_{10} [μg/m³]
Other sources
Background pollution
Works and extraction activities
Airport
Port
Road system [according to COPERT]
Road system [extra RSD]
Domestic and tertiary
Industrial and fugitives
100 μg/m³
50
40
0
Ajuntament de Barcelona
Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Origin of PM_{10} immissions in XVPCA's measurement stations in 2008
BARCELONA REGIONAL

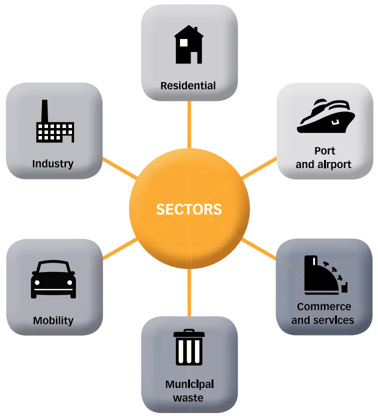
2.8 - Analysis by sectors

An analysis of the evolution of energy consumption of each of the sectors over recent years – residential, commercial and services, industrial, mobility, waste and major infrastructures- provides an excellent overview of the evolution of the relationship between the economic and social fabric of the city and energy and also the influence of the changes on the perception and use of these resources and the various situational changes on an international level.

In this respect, the relative importance of each sector in global energy consumption over the years has varied to the same extent as the city of Barcelona and its economic model. Thus, while during the early nineties the industrial sector accounted for the chief percentage of consumption, it is currently the residential, commercial, services and mobility which have gained weight.

This is the result of, amongst others, the decline in the industrial sector and the improved efficiency of production processes, the growth of the services section, increased tourism and phenomena related to individual behaviour in energy use, such as a stronger demand for mobility or climate control and the increasing use of electrical appliances.

FIGURE 126 | THE SECTORS STUDIED



2.8.1 - THE RESIDENTIAL SECTOR

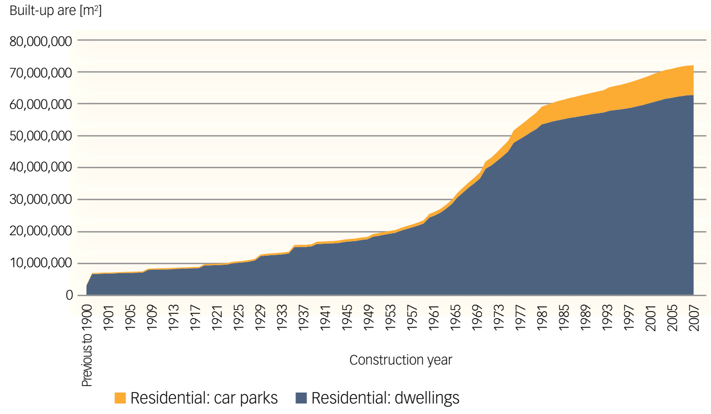
The housing stock of the city

Barcelona has a residential land space of 62.7 million square metres[30], more than half the total surface area of the city. The stock of residential buildings and car parks shows highly significant growth from the end of the forties of the last century with a sustained growth until the end of 2007.

Therefore, one of the main courses of action of this PECQ to reduce energy consumption and the associated emissions is to ascertain the characteristics of this housing stock, diagnosing the trends and deficiencies of the sector. The PECQ continues the study of the residential sector carried out in the Barcelona Energy Improvement Plan (PMEB), analyses the evolution of the housing stock since the year 1999, detects the new construction trends and assesses the changes in consumption habits.

The city's land register shows that residential buildings have an average age of 63 years, and prospective studies reveal that there will be a progressive ageing of the stock due to the scarcity of free land and refurbishment activities which prolong their useful life. A more detailed analysis of the refurbishment licences issued by Barcelona City Council in three districts shows considerable refurbishment work with approximately 11,600 licences issued in ten years. These figures place building refurbishment as a fundamental factor to be taken into account in the strategic analysis to enhance energy efficiency in the residential sector in Barcelona..

FIGURE 127 | ACCUMULATED DISTRIBUTION OF BUILT UP LAND SPACE FOR RESIDENTIAL USE IN BARCELONA BY AGE (1901-2007)



Source: Land Register 2007

The implementation of the Solar Ordinance of Barcelona, the Decree on eco-efficiency and, more recently, the Technical Building Code have changed the standards of new buildings since the PMEB was drafted, and therefore during the formulation of the PECQ, the energy and environmental implications of these new standards have also been analysed together with the affects on actual construction, studying the improvements they bring and the possibilities of going further towards more sustainable building. This, for the residential sector, the PECQ stresses as key challenges:

- Characterisation, from the energy viewpoint, of the current housing stock of Barcelona.
- Definition by type and energy study of newly built housing.
- Analysis of energy improvements in refurbishment work.

30. Without counting the surface area for parking spaces in most residential buildings (9,346,247 m²) or the communal areas of the buildings (stairways, meter rooms, etc.).

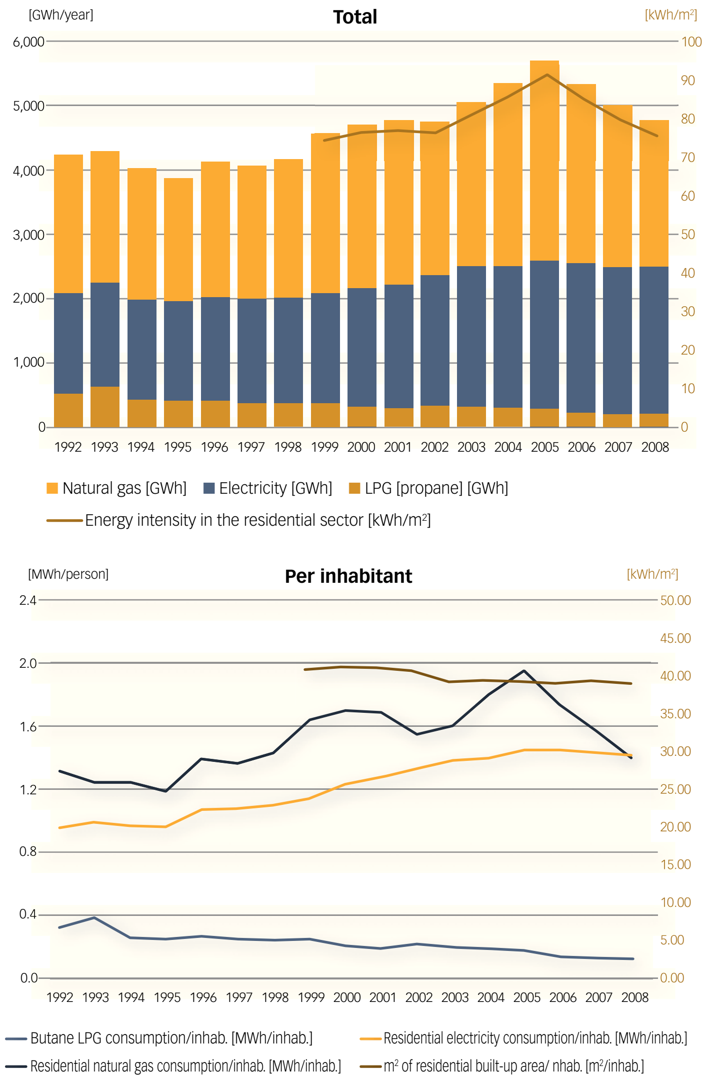
Evolution of consumption

In 2008, the residential sector in Barcelona consumer 4,794 GWh, 28% of final energy. This consumption was distributed almost equally between electricity and natural gas (48%, approximately of each energy source), while the remaining consumption was of liquefied petroleum gases LPG (butane), an energy resource which is progressively declining year after year.

Consumption records point to sustained growth in electricity consumption over recent years, due to the higher number of electrical appliances in homes (computers, dishwashers, air-conditioning...). The consumption of natural gas is also highly variable, due mainly to weather variations between years-, although demand for this energy source shows an upward trend.

Despite the reduction in residential land space per inhabitant – due to the construction of smaller flats and the increase in the number of occupants-, energy consumption per inhabitant has increased over recent years. This consumption, however, has varied from year to year due to fluctuations in natural gas demand.

FIGURE 128 | EVOLUTION OF FINAL ENERGY CONSUMPTION BY THE RESIDENTIAL SECTOR IN BARCELONA, TOTAL AND PER INHABITANT (1992-2008)



Source: ICAEN

CHARACTERISATION OF THE BUILDING STOCK

In order to gather more detailed information on the characteristics of the building stock of Barcelona and its thermal behaviour, the Energy Improvement Plan (PMEB) included a characterisation project via an analysis of the construction, architectural, urban and functional specificities and use of the housing and office stock. The use of a Geographic Information System (GIS) allows cross-referencing of parameters with the cartographic information of the city.

The methodology applied to characterising the housing stock, the definition of newly built buildings by type and the analysis of energy improvements in building refurbishment were as follows:

DIAGRAM OF THE CHARACTERISATION PROCESS AND ANALYSIS OF MEASURES

CHARACTERISATION OF THE RESIDENTIAL SECTOR

Definition of types of existing and newly erected buildings in Barcelona. Based on SIG data from the Land Registry and a series of architectural and urban-planning designs depicting the building reality in the city.

Determining energy demand by types of buildings. Analysis of the thermal behaviour of various types by using transient system simulation tools (TRNSYS).

Determining energy consumptions by types of buildings. The various types of energy systems are considered in order to obtain the corresponding consumption levels. Consumption levels for other uses such as lighting, facilities and other are also determined.

Determining energy consumptions in the construction sector in Barcelona. Global city emissions and consumption values are obtained on the basis of the characterisation made for each of the building types and of the extrapolation made in the scope of the city with SIG tools and the total consumptions of the sector.

Details of architectural designs by type of "post-war dwelling"

Details of simulation tools and resulting demands by type of building

Consumption matrix and representation by sources and uses by type of building

SIG map of city emissions

ANALYSIS OF MEASURES IN THE RESIDENTIAL SECTOR

Setting proposals for refurbishment and actions in new developments. Refurbishment measures are proposed with regard to the three most representative types of existing buildings. Such measures are defined from an architectonic and building perspective but they also include measurements. Similarly, proposals for improvement measures are made relating new developments (H9).

Evaluation of thermal demands (heating and cooling) in refurbishment and improvement actions. Each of the refurbishment and improvement measures are evaluated quantitatively.

Determining the savings in consumption (energetic, economic) and in emissions associated to the various refurbishment and improvement proposals for new development buildings.

Updating the characterisation of energy consumption of the building sector in Barcelona and new scenarios and policies for the future. The new characterisation of energy consumption of this sector in Barcelona, the future scenarios and the baseline for strategic city lines are determined on the basis of data resulting from previous stages and the analysis of works bids during the last few years.

The types of buildings

To conduct an energy characterisation of the residential buildings in the city, first it is necessary to ascertain their historic evolution. Until the unification of Barcelona with nearby municipalities (Gràcia, Sarrià, Les Corts, etc.) the City Plan of Barcelona was occupied by the old quarters of these towns, separated by fields and agricultural land.

To analyse the evolution of the buildings since that time down to the present, five major historic periods have been established which act as the starting point for a subsequent study of the different types of buildings currently to be found:

- FIRST PERIOD (UNTIL THE 19th CENTURY)
  In the old urban quarters- and particular that of Barcelona which was walled in-, the street plan was irregular, with narrow streets in which plots were opened with a small façade but with great depth. Originally, they followed the guild model, with space for the economic activity on the ground floor and dwellings on the upper floors. In many cases, the buildings were built upon or replaced.
  Construction methods evolved towards mud and irregular masonry bearing walls until, at the start of the 19th century, solid brick work became popular. Ground floors, however, continued to use Montjuïc stone masonry to prevent damp. Roofs were made with wooden beams with crossbeams made of plaster or ceramic tiles.
  From the thermal viewpoint, housing of this type is not well ventilated and the size of façade openings and the narrow streets did not make for proper lighting within the rooms. In winter they suffer the cold due to the lack of sunlight and low quality of the woodwork, although the compactness of the buildings signified they had little contact with the exterior.
  Dwellings located under the roof underwent greater cold in winter, while in summer they are very hot due to the lack of roof insulation.

- SECOND PERIOD (19th CENTURY- CIVIL WAR)
  With the approval of the Cerdà Plan in the mid 19th century and the subsequent aggregation of neighbouring municipalities, the city broke out of the limits which confined it and the Barcelona Plan takes shape. With the opening of new streets, the Eixample is built over the agricultural parcels, giving rise to larger plots than the old quarters although these were sometimes irregular.
  The larger plots and ordinances of the Cerdà Plan (despite the initial ordinances hardly being applied) led to buildings in which the construction techniques still resembled the earlier methods (brick bearing walls, wooden beams), but with improved quality of the finished product. The enlargement of parcels made it possible to build houses with a double orientation with better ventilation and offer greater alternate sunlight of rooms. Interior patios began to appear, which ventilated the interior areas, the beams were covered over with suspended ceilings, and galleries appeared in the centre of the building and buildings gained in height. As the 20th century progressed, in a manner similar to the change in architectural styles and tastes, construction technology also evolved together with certain building elements.
  There was no great change in construction methods or the construction sites themselves. The Eixample grew, but construction took place in the areas of the old quarters, and therefore the plots available had the traditional characteristics. There were also operations to dignify the old quarters (opening of Via Laietana, Passeig de les Drassanes, Ferran-Comerç…) which used the *"Eixample"* method in these areas.
  From the energy viewpoint, the Cerdà Plan had a very important advantage: the green space in the interior of the buildings which provide a highly favourable micro-climate in the summer months. Unfortunately, this idea was lost due to the building pressure, which is why the trend towards recovering the interiors of this area as public green spaces is so highly considered.
  The typical dwelling in the Eixample, arranged around a long passageway from façade to façade, works fairly well in terms of natural ventilation, despite the depth. In the case of large units which have subsequently been subdivided, the air flows cease to exist due to the separations built. The width of the streets makes for good sunlight and illumination of the rooms on the upper floors, while the dimensions of the patios do not make for good lighting of the interior rooms, especially on the lower

floors. In winter the dwellings are temperate, as the sun always shines on one of the two facades (except those near the corners of the interior patio), despite the lack of specific insulation signifying that the facades receiving little sunlight continue to be cold. They are cool in summer, as they can be well aired and solar protection is more effective. Only the rooms facing west on the upper floors have a tendency to heat up as the façade without insulation accumulates the heat during the afternoon. Dwellings located under the roof suffer greater cold in winter due to the lack of insulation of the Catalan roofs.

- THIRD PERIOD (POST-WAR – 70's)

The civil war signified a very important economic rupture and social and technological regression. The post-war period continued with traditional construction methods, based on the disappearance of prior assays and the scarcity of many material, especially steel, cement and energy.

In particular, as from the end of WWII and the autarky of Spain over several years (coinciding with the change of decade 1940-1950), there was an incipient economic recovery accompanied by migratory flows related to the growing industrialisation of the city's area of influence which led to swifter construction of buildings.

As from 1945 and until the sixties, there arose the figure of the *"polygon"* as a global form of urbanisation and construction, generally simple, small, inexpensive houses but in groupings of up to 4,000 dwellings, developed by official bodies or private companies and designed to absorb the immigrant labour.

The concrete structure model became consolidated (initially coexisting with bearing walls), closures were lightened (the air chamber took on the role of insulation which until then was provided by the façade thickness), windows became larger, the suspended ceilings were replaced by prefabricated plaster fillings, etc. These were years of great activity and also speculation, in which new technological methods and low cost construction materials appeared.

From the planning viewpoint, the District Plan in 53 raised the regulatory height and build on existing structures to avoid land saturation.

By type, and unrelated to the variety present in the polygons, dwellings became smaller, being reduced parallel to the facades. Thus, the same staircase gave onto four dwellings, two looking onto the street and the other two onto the interior patio. The patios went from playing a role as an ancillary element to being an essential source of ventilation and light for the dwellings.

Bearing walls virtually disappeared at the end of the sixties while cap and reticular roofs appeared together with flat beams instead of girders. Aluminium carpentry made its first appearance, although it was to coexist with wooden carpentry for many years, while steel ceased to be used.

The division into interior and exterior dwellings prevents direct cross ventilation which only takes place between the façade and the interior patios, without positive results. The patios in general are too small in proportion to the height to be ventilated, and especially to be illuminated. Each dwelling faces only one way, and its behaviour therefore depends on this orientation. The width of the streets makes for good sunlight (according to the orientation) and illumination of the rooms on the upper floors, yet the dimensions of the patios do not make for good lighting of the interior rooms, especially on the lower floors. The general lack of insulation and larger glass surfaces make the dwellings colder in winter, except for those receiving a large amount of sunlight. In summer they are hot, as the difficulty in ventilating them is compounded by the lack of insulation and the little effectiveness of certain types of protection from the sun. Dwellings located under the roof suffer greater cold in winter, while in summer they are very hot due to the lack of roof insulation. The low original quality of the exterior woodwork signifies there are many leaks.

- FOURTH PERIOD (1970-2000)

In the mix-sixties, a new General Plan came into effect which reduced the possibilities of building densification allowed under the previous Plan; it reduced the regulatory height, prohibited upward construction, increased the size of the patios and limited the construction depth.

The most standard dwellings lost in surfaced areas – together with the family units becoming smaller – to a size of some 90 m^2, with four rooms.

In 1979, due to the 1973 oil crisis, the first and only state thermal standard was approved (NBE-CT-79) which sought energy saving, especially with regard to the heating of buildings.

Despite the initial reluctance, the lack of proper compliance in many cases and the weak demands of the insulation standards, the habitability of the dwellings improved, especially the most exposed cases (those highly affected by sunlight located below the roof, etc.). Socially, insulation and double glazing were perceived as quality values and used as sales arguments.

In general terms, the shortcomings in thermal performance of buildings from the earlier period continued. The division into interior and exterior dwellings prevented direct cross ventilation. The patios continued to be too small in proportion to the height of the building for ventilation and lighting purposes, especially when covered by skylights. Despite there usually being solar protection, it often prevented simultaneous ventilation as it could not be regulated (folding blinds).

In parallel, the end of the *"development"* stage of the Franquist regime led to smaller population flows which started to achieve a higher standard of living. It was no longer a case of finding a home in whatever manner. The population started to demand a certain *"quality"*, assisted by advertising campaigns of brands of insulation, carpentry, etc.

The errors and shortcomings in the quality of the construction started to appear, especially in the polygons, which saw a more active resident movement to achieve a minimum quality level. During these years construction methods barely evolved, and with the exception of the improved insulation, they continued to be built in the same manner as before.

In Barcelona, construction emigrated to the neighbouring municipalities. Only specific areas of the city centre saw any activity to substitute obsolete constructions or to use up the few remaining building sites.

Property prices rose during the mid-eighties, probably as a result of economic movements related to the Olympic Games of 92 (the designation was made in 1986). Preparations for the Games led to one of the most active periods of the century: Opening up of the Ring roads, the transformation of Poble Nou, the Olympic Village… In the Olympic Village (and also in Vall d'Hebron), the global concept of the district and the lack of time imposed the adoption of new building and technological models: Small partitions, dual orientation without patios, plasterboard partition walls, centralised refuse collection systems, urban service galleries…

Once the Olympics had concluded, building within the city returned to its earlier pace with the normal economic fluctuations. This period was, however, marked by two factors: There was increasingly less free land at higher prices. This affected the final price of the dwellings, although the improved communications – the Ring roads and trains or buses- led part of the population to live outside the city, while others did likewise for reasons unrelated to housing prices.

- CURRENT AND FUTURE TRENDS

Sociological changes over recent years have led to the appearance of different types of housing users which entails diversified demand. From dwellings occupied by a single person, single-parent families or traditional family units to dwellings with excessive occupancy as a result of immigration.

We should, however, underline that construction methods have also undergone a significant change thanks to various standards and directives which have addressed the subject of energy saving and efficiency in building.

In the EU, we should note Directive 2002/91CE of the European Parliament and Council dated 16 December 2002 on energy efficiency in buildings. Its objective is to take action in relation to energy calculations and minimum efficiency requisites, energy certification and regular inspection of boilers and air-conditioning systems.

The Technical Building Code (approved by Royal Decree 314/2006, 17 March and partially amended by Royal Decree 1371/2007, 19 October), is the legal framework which regulates the basic quality requirements which buildings must comply with, including installations so as to meet the basic safety and habitability requisites. Some of the basic requirements regulated are safety in the event of fire, soundproofing and energy saving.

On an autonomic level, we should highlight the Eco-efficiency Decree (Decree 21/2006, 14 February). This decree contained environmental and eco-efficiency parameters (for water, waste, construction materials and systems) in newly constructed buildings, those older buildings which are reconverted and major refurbishment work. It also affects buildings used as housing, for collective residential and administrative, teaching and health purposes.

Since 1999 Barcelona has had the thermal solar Ordinance (which forms part of the general Ordinance on the urban environment), with the aim of promoting and regulating, via local legislation, low temperature solar energy installations to produce hot water for buildings. This legislation on thermal solar capture was amended in March 2006.

The emergence of new requisites and the directives mentioned above have also led to the compulsory conditions and accessibility of roofs, if only for the maintenance of the installations which are an increasingly common feature in buildings. This has created a new means of reusing rooftops, traditionally used for hanging out clothing but underutilised or inaccessible in the more recent types.

Based on this analysis of the evolution of construction throughout history in Barcelona, a proposed classification of buildings is made which are mostly used for residential purposes into different building types, in accordance with the period constructed and other parameters (planning, construction, operational). The thermal performance of the buildings is also simulated, taking into account the technology available in the dwellings, the consumption habits of their inhabitants and the influence of the building envelope and neighbouring buildings.

Of the land space in Barcelona (62,774,888 m²), 89.4% is represented by five defined building types (56,133,904 m²), while the remaining 10.6% (6,640,984 m²) are mostly residential buildings which do not correspond to any defined profile type. By analysing the cartographic database and the data of the land register, the type H6 stands out as the most common type, accounting for 51% of the square metres of dwelling land space in Barcelona.

TABLE 33 | THE CHIEF TYPES OF BUILDINGS IN BARCELONA

TYPE	Short description	Construction period
H1 and H2	Dwelling in the old part of town	Specially up to the end of the 19th Century, although more recent ones can be found in areas where plot division made it easy.
H3 and H4	Pre-Civil War dwelling (Eixample area)	From the beginning of Barcelona's expansion to the Eixample (mid 20th Century) up to 1930's.
H5 and H6	Post-Civil War dwelling (development and expansion in housing estates)	From the post-war reconstruction period (1940) up to Late-Development Policy (1979)
H7	Post-thermal rules dwelling	Post-thermal rules dwelling
H8	Dwelling following the year 2000 trends	2000-2007
H9	Post-Technical Building Code building	Buildings erected according to CTE regulation

FIGURE 129 | DISTRIBUTION OF BUILDINGS IN BARCELONA BY TYPE

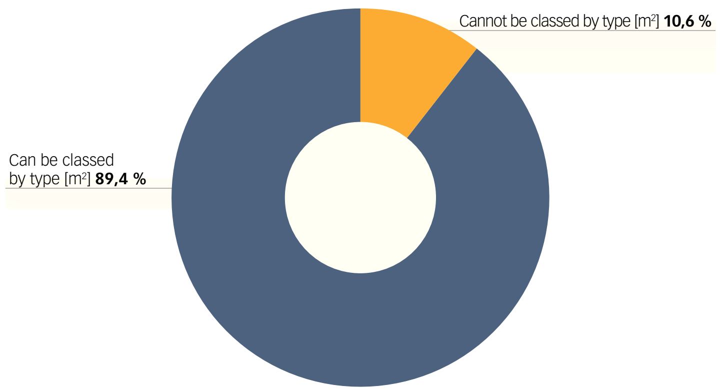
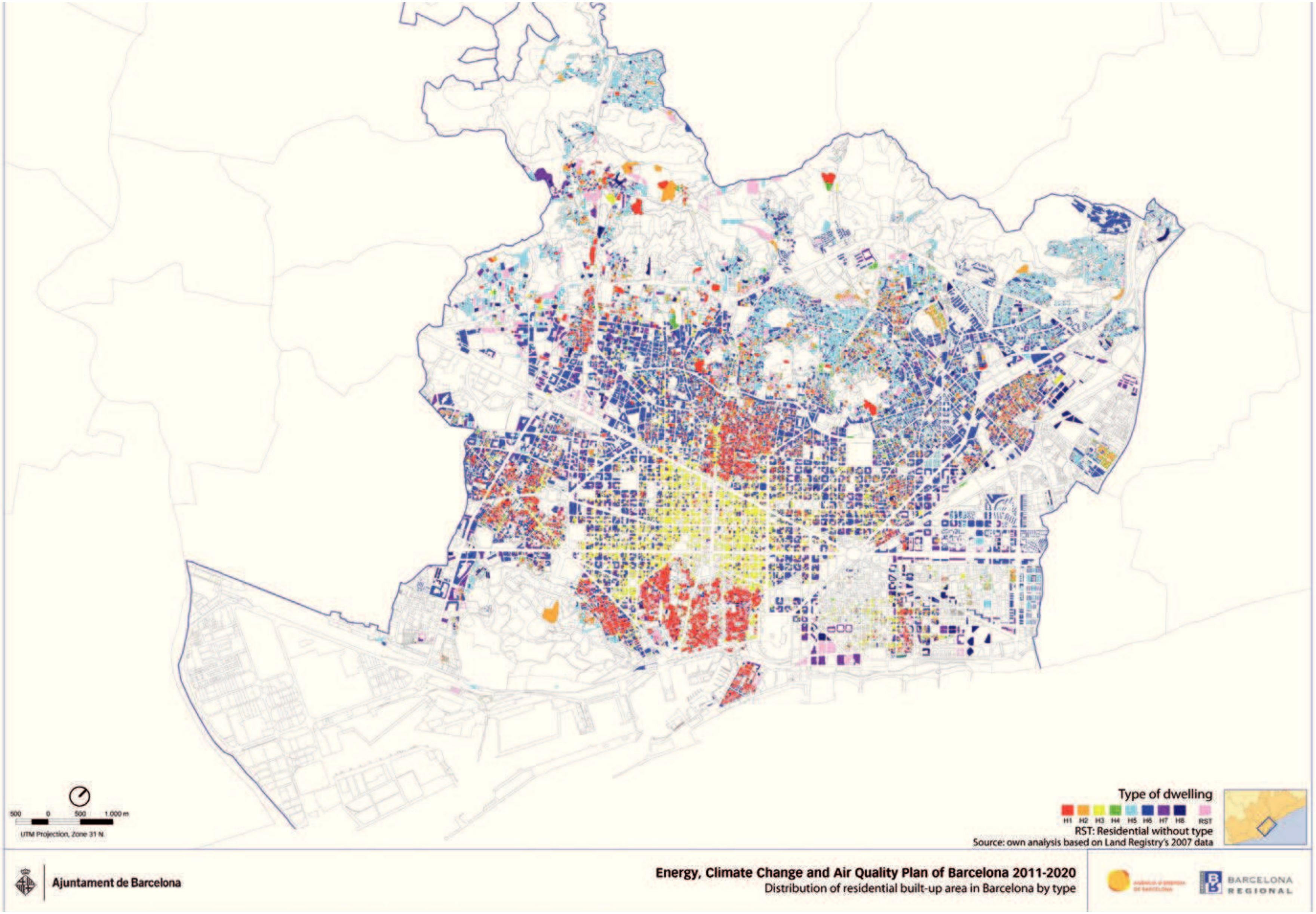


TABLE 34 | DISTRIBUTION OF BUILT UP LAND SPACE IN BARCELONA BY TYPE

	m² dwellings	%	number of dwellings	%
H1	5,257,842	9%	79,607	11%
H2	642,895	1%	10,667	1%
H3	7,304,277	13%	84,315	12%
H4	136,048	0%	2,041	0%
H5	5,701,109	10%	87,023	12%
H6	28,566,816	51%	358,393	50%
H7	6,544,407	12%	72,975	10%
H8	1,980,510	4%	24,894	3%
Total	**56,133,904**		**719,915**	

Source: Municipal Statistics Institute Land Register 2007


500
0
500
1.000 m
UTM Projection, Zone 31 N.
Type of dwelling
H1 H2 H3 H4 H5 H6 H7 H8 RST
RST: Residential without type
Source: own analysis based on Land Registry's 2007 data
Ajuntament de Barcelona
Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Distribution of residential built-up area in Barcelona by type
BARCELONA REGIONAL